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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 119.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE DISPERSION OF THE GIPSY MOTH.

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BY

A. F. BURGESS,
Expert in Charge of Biological Investigations.

ISSUED FEBRUARY 11, 1913.

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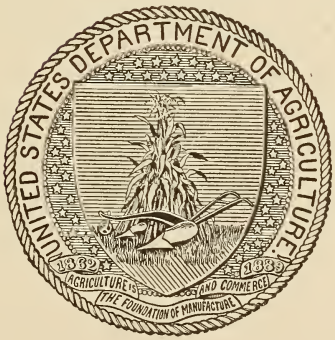

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., July 24, 1912.

Sir: I have the honor to transmit the manuscript of a paper entitled "The Dispersion of the Gipsy Moth," which is a result of extensive studies made to determine the means by which this insect is spread. The gipsy moth has caused enormous injury to the horticultural, forestry, and shade-tree interests in the New England States, and the results of the investigations made have an important bearing on the proper methods of restricting the further spread of this serious pest.

I recommend the publication of this manuscript as Bulletin No. 119 of this bureau.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE DISPERSION OF THE GIPSY MOTH.

INTRODUCTION.

The dispersion of any insect that has been introduced, accidentally or otherwise, into a new country offers an interesting opportunity to study the elements which aid in bringing about its transmission from point to point within that country, and this is particularly true concerning one of so great economic importance as is the gipsy moth. When the first work to suppress this insect was taken up in the early nineties an attempt was made to determine all the means by which the insect was spread, and since that time any data bearing on the spread of the pest have been eagerly sought and carefully studied in the hope that better methods could be found for its control. The region surrounding Medford, Mass., where the gipsy moth was introduced in 1869, is the center of one of the most thickly populated sections of the United States; hence there was an unusual opportunity for the spread of the insect by artificial means. In spite of the work that has been done and the observations that have been recorded it has remained until the last two years for a demonstration to be made of the manner by which this insect is spread, to the greatest extent, by natural means.

MEANS BY WHICH INSECTS ARE SPREAD.

One of the principal methods of insect locomotion and of spreading is by flying, and there is little chance of preventing the spread of a strong-flying introduced species which has become thoroughly established. The continued spread of the elm leaf-beetle and of the brown-tail moth illustrates how flying insects are dispersed.

There is, however, another class of insects which does not spread by flying. Several distinct types exist, and among them may be mentioned such insects as the San Jose scale and other closely related species. The structure of the females of this group is such that they remain fixed before becoming sexually mature; hence the distribution of the species is confined, so far as natural means is concerned, to the dissemination of the young, which have the ability to move about for a limited period. The adult insects are spread by artificial means on nursery stock and on living trees or shrubs that are shipped from one locality to another for planting or propagation. The brown-tail moth has also been distributed on nursery stock, but it is carried in this way while the small caterpillars are in the hibernating webs where they pass the winter.

While the gipsy moth does not belong to the same class as the scale insects just mentioned, it resembles them inasmuch as it is not spread by the flying of the adult, for although the females are provided with wings, they are unable to fly, owing to the extreme weight of the body. Dispersion, therefore, is greatly restricted in this stage of the existence of the insect, and this is important, as it bears directly on the control of the species.

INVESTIGATIONS OF THE DISPERSION OF THE GIPSY MOTH.

Investigations which were carried on during the early nineties have been fully treated in the report on the gipsy moth by Forbush and Fernald, published by the Massachusetts State Board of Agriculture in 1896, natural and artificial dispersion being considered on pages 94–116. Although it appeared at that time that excellent opportunities were afforded for studying the dispersion of this insect, still it must be remembered that the pest was abundant in relatively few localities during the years covered by that report, especially when the conditions existing in later years are considered in comparison. It is evident that the extent of distribution of any insect depends largely upon the abundance of the species, and if large areas are badly infested migration is often necessary in order that many of the individuals may secure sufficient food.

The dispersion of the species, as treated in the above mentioned report, was considered as local and long distance. The former condition was brought about by egg clusters being broken and scattered by birds or other animals that frequent infested trees. Clusters were also carried on driftwood (see Pl. I), and those deposited on leaves (see Pl. II) were sometimes distributed by the wind. The caterpillars were occasionally found clinging to the bodies of animals or to the clothing of persons who had visited infested places and were carried short distances in this way.

Many colonies were established in remote districts by the carriage of the larvæ on vehicles, and egg clusters were sometimes transported on cordwood or lumber products shipped from infested forests. (See Pl. III.) The distribution of caterpillars upon vehicles was considered so important when the gipsy-moth work was begun in 1891 that inspectors were stationed along the main highways to stop and examine all vehicles and to destroy any caterpillars found before allowing them to pass out of the infested area. This precaution was entirely warranted in view of the discovery that many farms had become infested by the transportation of caterpillars on vehicles. Places infested in this manner, however, were usually occupied by milkmen, peddlers, swill gatherers, or persons whose business caused them to drive regularly to and from the city during the summer, or to neighborhoods that were badly infested with the gipsy moth.

GIPSY-MOTH EGG CLUSTERS ON CHARRED WOOD ON THE EDGE OF A STREAM, SAUGUS, MASS., MAY, 1912.

Showing how this species may be dispersed on driftwood. (Original.)

FEMALE GIPSY MOTHS DEPOSITING EGGS ON OAK FOLIAGE, MELROSE, MASS.

Arrows point to pupæ, moths, and egg clusters. (Original.)

LUMBER PILES AT YORK, ME.; GIPSY-MOTH EGG CLUSTERS ON UPTURNED BOARD AT RIGHT OF FOREGROUND.
(FROM HITCHINGS)

The efficient work which was carried on by the Massachusetts State Board of Agriculture during the early nineties rendered the continuance of vehicle inspection unnecessary, as the moth had been greatly reduced in numbers and very few badly infested localities could be found. At the time the work was abandoned in 1900, 34 towns and cities surrounding Boston were slightly infested. A few isolated colonies were present outside of the limits of this area, but in most cases these had been reduced almost to the point of extermination, and in several colonies none of the insects had been found for two or more years, in spite of the fact that careful examinations were made annually. It should be said that very little if any of the territory in the infested area was what would be considered now as badly infested, and owing to the thorough manner in which the work was prosecuted the danger of spread was reduced to a minimum.

CONTROL WORK ABANDONED.

In the winter of 1900 suppression measures were abandoned by the State of Massachusetts, but during the next five years considerable individual effort was expended to protect the trees in the residential sections, particularly by owners. The infestation became so serious, however, in the summer of 1904, and the depredations of this insect were so severe, owing to its remarkable increase in numbers, that action was taken by the State in the spring of 1905, and money provided for the purpose of affording relief and preventing the destruction of trees in towns and cities as well as of attempting to control the moth throughout the infested area.

The State force was organized by Supt. A. H. Kirkland, and conditions in the territory, which was the central part of that which was infested when the work was stopped, are well described by the following extract from his first annual report.[1]

As would have been expected, during the year 1900 and 1901 but little notable damage was caused by the gipsy moth, although evidence was not wanting to the trained observer that it was rapidly multiplying in woodlands and on neglected private estates. It was apparent that nonresident property owners particularly paid practically no attention to the increase of the insect and that farmers and others owning infested woodland areas were unwilling, because of the expense, to fight the insect. In 1902 numerous estates were severely injured throughout the central district, while woodland colonies of some magnitude had developed from which the insects were swarming in all directions. The summer of 1903 showed that the moth had established itself again in alarming numbers in various parts of the infested district. Serious colonies had developed in the woods of Arlington, Medford, Saugus, and Malden, and the Lynn Woods colonies had assumed notable proportions. In 1904 it was apparent to all that the gipsy moth had developed to a remarkable extent, reinfested the areas from which it had been cleared, and even extended its bounds into previously noninfested

[1] First Annual Report of the Superintendent for Suppressing the Gipsy and Brown-Tail Moths, 1906, p. 12.

territory. The caterpillar outbreak was sufficient to convince every tree lover of the necessity of concerted action against the moths. While in many places in the afflicted district the trees under the charge of municipal authorities were cared for with considerable success, private estates and woodlands in June and July presented shocking scenes of devastation. In many places the work of fire could not have been more thorough or alarming. From Belmont to Saugus and Lynn a continuous chain of woodland colonies presented a sight at once disgusting and pitiful. The hungry caterpillars of both species of moths swarmed everywhere; they dropped on persons, carriages, cars, and automobiles, and were thus widely scattered. They invaded houses, swarmed into living and sleeping rooms, and even made homes uninhabitable.

GIPSY-MOTH WORK RESUMED.

It must be noted that the conditions above described were most favorable for the dispersion of this insect, and in order to determine so far as possible the territory which had become infested, inspectors from the office of the superintendent made an examination of a large area outside of that known to be infested when the work was stopped. Of necessity this examination was hurriedly done, owing to the fact that a sufficient number of trained men could not be secured in the limited time available, and also because a large number of the more experienced workers had to be employed in fighting the intolerable conditions in the central towns. The results of the scouting work, however, showed that the gipsy moth was present in 124 towns and cities in Massachusetts. Seven infested towns were also found in New Hampshire, extending from the Massachusetts line along the sea-coast to and including Portsmouth, so that the entire infested area proved to be six times greater than when the work was abandoned. Each year since 1905 more or less scouting work has been done by the State of Massachusetts in the towns outside of the known infested area, and in Maine, New Hampshire, Rhode Island, and Connecticut large sections have been examined by scouts working under the direction of Mr. D. M. Rogers, superintendent of moth work for the Bureau of Entomology, United States Department of Agriculture, and every year additional infested territory has been found. As a rule very few egg clusters are found in the outside towns, but it should be stated that the examination is confined to the roadsides, residential sections, and orchards, it being impossible to examine all the large forest areas involved.

The same factors which previously resulted in the dispersion of the insect were found to be operating, but the danger had been greatly increased owing to the development of many high-speed and long-distance trolley lines which conveyed people from the centers of population to the rural districts rapidly and in many cases without changing cars. These increased transportation facilities afforded an excellent opportunity for the distribution of gipsy-moth

caterpillars, and the presence of the insect in woodland surrounding lakes and ponds which were frequented by camping parties was the natural result. During midsummer, when caterpillars were abundant, they could frequently be seen crawling on the clothing of people on electric cars and sometimes have been observed on the seats and running boards. In this way they are often carried considerable distances.

THE AUTOMOBILE AS A MEANS OF DISPERSING THE GIPSY MOTH.

Perhaps no single form of transportation has caused so wide a dispersion of this insect as the automobile. When the gipsy moth was most abundant during the nineties it was seldom possible for caterpillars to be conveyed on teams or wagons more than 20 miles in a single day, but with the advent of the automobile this danger was greatly increased. In fact, since this mode of travel has become popular the traffic between the cities in eastern Massachusetts and the seashore and mountain regions in Maine, New Hampshire, and Vermont has increased remarkably, and the spread of the insect has been proportionately greater.

The lines of automobile travel are usually along trunk roads, many of which are bordered by badly infested woodland. These conditions afford an excellent opportunity for the young caterpillars to spin down from the trees and to be carried away by any moving object with which they come in contact. Cases are on record where city residents who own country or seashore places have caused them to become infested by journeying back and forth by automobile. So many cases of this kind have been found that it is now considered one of the easiest means by which the insect is spread. Automobile traffic is very heavy in June, when the gipsy moth is most likely to be carried in the caterpillar stage.

OTHER MEANS OF DISPERSING THE GIPSY MOTH.

Another means by which the gipsy moth is dispersed to outlying regions is through the unintentional carriage of caterpillars or egg clusters by visitors or travelers. In 1906 this insect was found in small numbers on the grounds of the National Soldiers' Home at Togus, Me. The nearest known infestation at that time was 81 miles away, and, from the condition of the infestation and the circumstances connected with it, it seemed probable that the insect had been brought there either in the egg or caterpillar stage on the clothing or among the effects of some of the inmates or visitors who came from the infested area in Massachusetts. Isolated infestations are continually being found in towns some distance from the infested area, especially on farms or in camps where parties from Boston and vicinity spend their summer vacations.

In the fall of 1910 a flourishing gipsy-moth colony was found on a farm at Charlton, Mass. The worst part of the infestation was in a small orchard near the farmhouse and in a row of trees some distance away which bordered on cultivated land. Inquiry showed that for a number of years it had been the custom for the owners of this farm to take children from Boston and vicinity for summer boarders. The vacation of each boarder usually lasted about two weeks, so that they were continually changing, and there is no doubt that gipsy-moth caterpillars or egg masses were brought from the infested regions in the baggage of the visitors.

Many similar cases might be cited, but this will suffice to illustrate the ease with which this insect may be carried long distances.

In December, 1909, a flourishing colony of the gipsy moth was found in the residential section of Wallingford, Conn. This is more than 100 miles from the nearest badly infested area. Examination showed that the worst infested trees were in the business section, and many of them were in the rear of a grocery and provision store. Supplies of vegetables, such as early lettuce, cucumbers, and tomatoes, had been received in season by this store from market gardens located near Boston, and there seems to be little doubt that egg clusters of the gipsy moth had been transported inadvertently on the boxes or in the packing material.

RELATION OF BIRDS TO THE DISPERSION OF THE GIPSY MOTH.

During the past few years the scouting operations in Massachusetts and New Hampshire have resulted in the discovery of gipsy-moth colonies in regions inaccessible to travel, and often in places which would seldom, if ever, be frequented by man. This condition of affairs has occurred so often, and an explanation for the presence of these colonies became so difficult, that it seemed desirable to take up the subject in a more thorough-going manner for the purpose of determining whether the insect might be distributed by some other means. In some of these cases it is possible that the colonies might have started from caterpillars that had been dropped by birds, but the distances between many of them and known infested regions were so great as to render this theory in most cases highly improbable. Furthermore, when caterpillars are picked up by birds they are usually injured to a greater or less extent, and the chances of their developing so that vigorous colonies would result in a few years are very remote. Another factor in relation to the influence of birds on the spread of the gipsy moth, and one which has received much serious consideration, is the possibility of their feeding upon the eggs of the species and distributing them in the excrement. If fertile eggs of the gipsy moth should be eaten and pass through the alimentary canal of some of our insectivorous birds without sustain-

ing injury, it would undoubtedly offer a valid explanation of the cause for some of the outlying colonies which have been found. In the report of Forbush and Fernald, already cited, detailed accounts are given of the part played by practically all the insectivorous birds which are at all common in eastern Massachusetts. At the time the observations were made a large number of trained field observers were constantly employed, and few, if any, of these reported that birds were found feeding upon eggs of the gipsy moth. In fact, the report states that the only bird that has been found feeding upon these eggs in the field is the English sparrow, and, as it is normally a grain-feeding species and one that frequents cities or centers of population, it is doubtful whether the moth would be dispersed to any great extent if it were possible for the eggs to pass through the bird without injury.

Fortunately, during the winter of 1909–10 two sets of experiments were conducted for the purpose of determining whether gipsy-moth eggs would pass through the alimentary canal of birds without injury. These tests were made independently, and in both cases it was necessary to disguise the eggs in other food or force the birds to feed upon them. One set of experiments was begun in February, 1910, by Mr. C. W. Collins,[1] of the parasite laboratory of the Bureau of Entomology. He used a number of English sparrows and a single pigeon.

The sparrows were fed by placing gipsy-moth eggs in their mouths and requiring them to take a swallow of water to wash them down. Of 356 eggs fed in this way 142 were found intact in the excrement and the balance were broken during the process of digestion or remained in the gizzard. Only seven eggs hatched, which shows that under this artificial treatment the chances for survival of the eggs are very small. None of the eggs fed to the pigeon hatched after being voided.

These experiments indicate the extreme improbability of either of these birds selecting gipsy-moth eggs for food, and the chances of the insect being disseminated in this way appear very slight, both on account of the injury to the eggs in passing through the bird and because the distances of migration of the species are relatively small.

The other set of experiments was conducted by Mr. Wm. Rieff,[2] of the Bussey Institution, Harvard University, during March of the same year. As no native birds were available for the tests the following species were used: German canary bird, English yellow-hammer, English chaffinch, Japanese robin, screech owl, and carrier pigeon. The eggs were disguised in food, such as bread crumbs. In the case

[1] Some Results from Feeding Eggs of *Porthetria dispar* to Birds. Journal of Economic Entomology, vol. 3, no. 4, Aug., 1910, p. 343.

[2] Some Experiments on the Resistance of Gypsy Moth Eggs to the Digestive Fluids of Birds. Psyche, vol. 17, No. 4, Aug. 1910, p. 161.

of the Japanese robin they were placed inside the larvæ of the meal beetle (*Tenebrio molitor*), while those fed to the screech owl were inserted in a freshly killed mouse.

Of 52 eggs that passed through the Japanese robin three hatched, while of 112 eggs vomited by the screech owl with the remains of the mouse seven hatched. No hatching resulted in the experiments with the other birds.

The writer says:

> To sum up the details of these various experiments it is seen that gipsy-moth eggs can withstand the action of the digestive fluids of birds belonging to at least two families, Turdidæ and Bubonidæ, without suffering any, or only slight injury. In regard to the large family, Fringillidæ, also an insectivorous group, I am inclined to believe that these birds might also occasionally distribute gipsy-moth eggs in spite of the negative results obtained in my experiments.

These conclusions seem too sweeping because of the large percentage of the eggs that failed to hatch, and when the conditions under which the birds were fed is considered it is doubtful whether comparable results would be secured under natural conditions.

The Bubonidæ and Fringillidæ are not, for the most part, insectivorous birds, and it is doubtful if the latter would, except in rare instances, eat eggs without crushing them or at least attempting to break away their outer covering, as this is their usual habit when feeding on seeds, which are their natural food.

Whether eggs would pass through the alimentary canal of some of our less domesticated insectivorous birds unharmed is an open question, and one very difficult to settle, owing to the fact that these wild species can not be experimented with in confinement in any satisfactory way. It should also be noted that the digestive process in birds is more rapid under natural conditions than when they are confined for experimental purposes; hence it may be that in nature a larger percentage of eggs would withstand the digestive action, but the distance that they could be carried would be correspondingly reduced. The main question, however, appears to be whether birds actually eat eggs of the gipsy moth in the field.

Men engaged in the moth work frequently find egg clusters which have been broken, and sometimes in such a condition that one might conclude that they had been pecked at by birds. Clusters are sometimes broken by squirrels or other animals, and not infrequently this is charged up to birds. Mr. John A. Farley, one of the agents of the Massachusetts State forester's office, reports the following observation, which shows how carefully matters of this nature must be investigated in order to prevent error. On visiting a wooded area where it had been reported that birds were feeding on gipsy-moth eggs and where the clusters showed every indication that this

conclusion was correct, he found that the chickadees (*Penthestes atricapillus*) were working among the clusters and were apparently feeding. On making a more thorough examination he found that a few small white-pine seeds had been stored away in the cavities that were made by the birds in the gipsy-moth egg clusters. No egg-shells or other evidences of feeding were found, and later Mr. Farley saw the birds depositing the seeds. Later in the season an examination was made and the seeds previously secreted were missing. Dissections have shown that pine seeds are a favorite food of this species and that they are often collected and stored for a winter food supply. The reliability of these data is unquestioned and throws an interesting light on the subject.

It has been suggested by Mr. William Brewster, the well-known ornithologist of Concord, Mass., that the gipsy moth may be spread in the egg stage by crows, hawks, and other large birds that make nests (Pl. IV) of large twigs, as it would be possible for them to carry material which was infested with egg clusters. This may happen in some cases, but it seems probable that it would result in local rather than long-distance dispersion.

In view of the results secured by the experiments above mentioned and of the observations cited it seems that the evidence is wholly inadequate to prove that birds were responsible for distributing the gipsy moth to the large area which was annually becoming infested. Furthermore, towns where only one small infestation was found might, the following year, be infested in 20 or 30 different localities, all of which were remote from influences which would favor artificial means of spread. As the first infestation found in a town is usually small and is thoroughly treated, no reasonable explanation could be given for the presence of so many colonies the following year. The fact, also, that many of these outbreaks were located in places that were seldom frequented by men or animals indicated strongly that some other natural means must assist the insect in becoming generally dispersed.

CONTINUED DISPERSION OF THE SPECIES UNEXPLAINED.

For several years this matter was thoroughly considered by the officials connected with the gipsy-moth work, but it seemed impossible to come to any conclusion as to the means whereby so many small isolated colonies had become established. The theory was advanced that occasionally one of the female moths, developed in a badly infested colony where the adults were abnormally small on account of an insufficient food supply for the larvæ, might be able to fly, and in this way cause the dissemination of the pest. No facts to prove this theory have ever been secured, and although this might happen occasionally it wholly fails to explain the reason for numerous small

colonies which are found long distances from any badly infested area. Isolated colonies have been usually so far away from infestations that it would have been practically impossible for small females to have covered the distance by flying.

SUGGESTIONS CONCERNING THE SPREAD OF LARVÆ BY THE WIND.

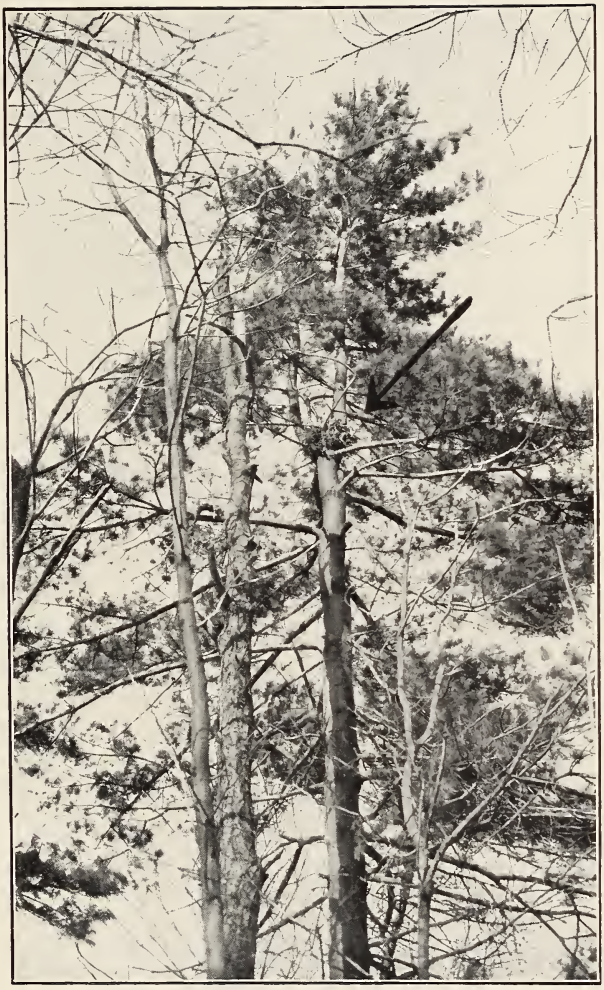
In the fall of 1909 Prof. E. D. Sanderson, who was then entomologist to the New Hampshire Agricultural Experiment Station, and who was deeply interested in the work of suppressing the gipsy moth, suggested that the caterpillars of this insect might be carried by natural means, and later he wrote to Dr. L. O. Howard, Chief of the Bureau of Entomology, calling attention to an article in the Standard Natural History relative to the peculiar hairs on the young caterpillars and suggesting that they might assist the larvæ in being carried by the wind. An examination of the literature showed that the matter had been mentioned by Forbush and Fernald in 1896 and that the hairs had been described by Wachtl and Kornauth in a publication relating to experiments in the forests of Austria in 1893. This paper deals principally with hairs of peculiar structure which are found in the first-stage larvæ of the nun moth (*Psilura monacha* L.) and states that similar hairs are found on the first-stage larvæ of *Porthetria dispar*.

These hairs are not present on the caterpillars in the later stages, and as they are provided near the base with a globular enlargement, which the authors believed to be filled with air or gas, they were called aerostatic hairs and the globes aerophores. They state that the first-stage nun larvæ are carried long distances by the wind, and one might assume that the same is true of the gipsy-moth larvæ, as they are provided with similar hairs.

A microscopic examination of one of these first-stage caterpillars shows that two kinds of hairs arise from the tubercles which are arranged in rows on the body. Only a few slender acuminate hairs, some of which are nearly half as long as the caterpillar, arise from each tubercle (Pl. V), but many short hairs are present which have a small globular swelling near the base. Whether these aerophores actually aid in making the caterpillars more buoyant, as is suggested by the authors above mentioned, is not positively known, but it was of great importance to know whether dispersion is actually brought about by means of the small larvæ drifting in the wind.

EXPERIMENTAL WORK.

In the spring of 1910 a preliminary experiment was tried in the laboratory by releasing caterpillars, which had been encouraged to spin as much silk as possible, in front of an electric fan. Although



CROW'S NEST IN TOP OF PINE TREE, POSITION INDICATED BY ARROW.

Gipsy-moth egg clusters are frequently found in or around such nests. (Original.)

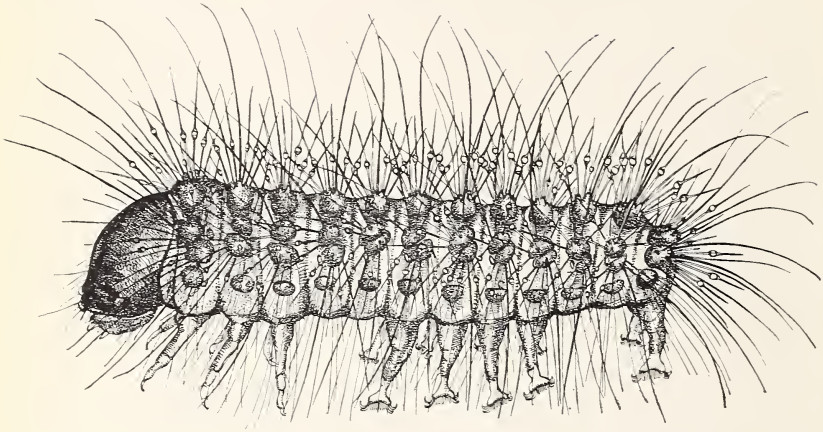


FIG. 1.—FIRST-STAGE LARVA, SHOWING THE TWO KINDS OF HAIRS. ENLARGED. (ORIGINAL.)

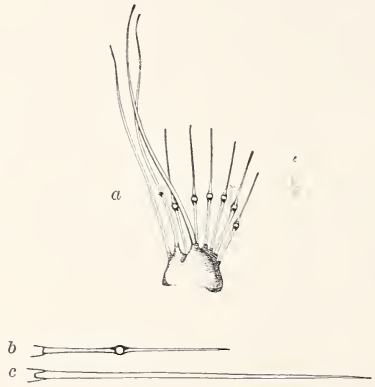
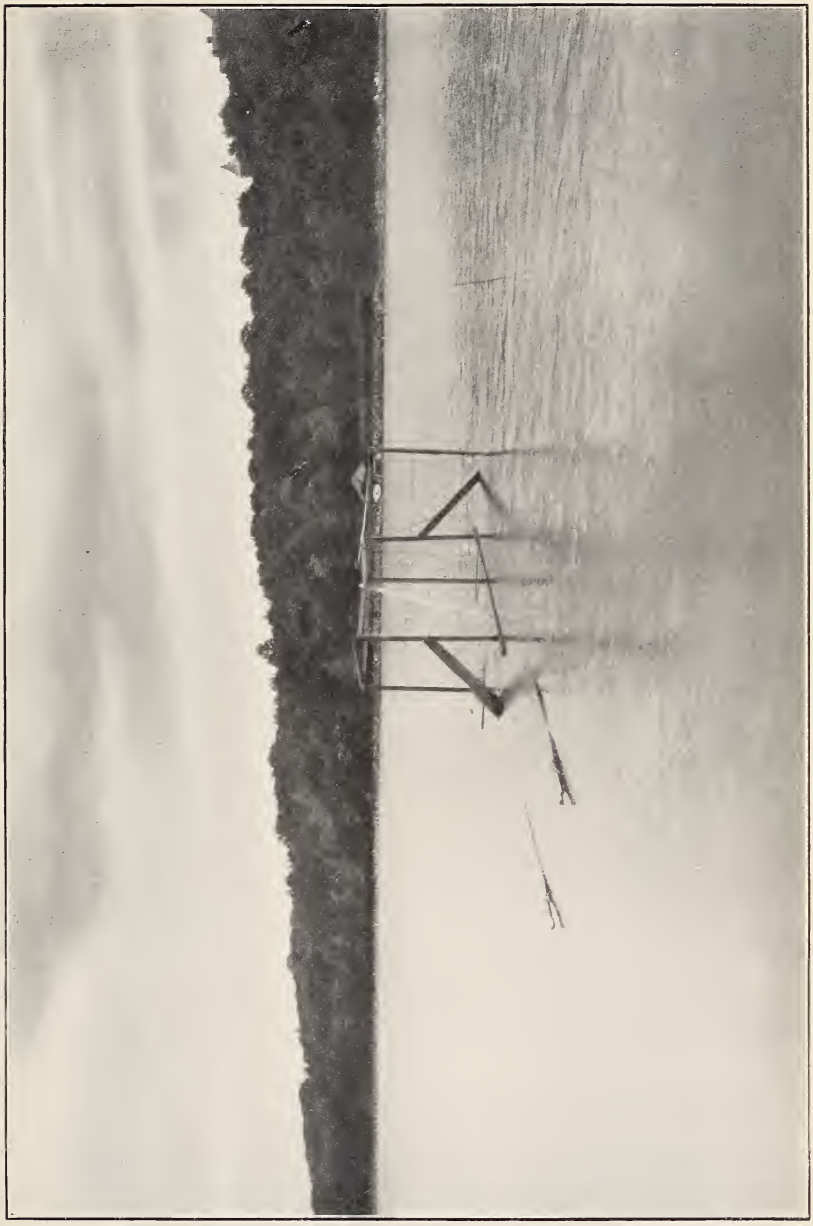


FIG. 2.—*a*, TUBERCLE FROM FIRST-STAGE LARVA, SHOWING HAIRS; *b*, AEROSTATIC HAIR; *c*, ACUMINATE HAIR.

a, Much enlarged; *b*, *c*, more enlarged. (Original.)

GIPSY-MOTH CATERPILLAR SHOWING AEROSTATIC HAIRS.



TRAP MOORED IN POND TO TEST AVIATION OF GIPSY-MOTH LARVÆ. (ORIGINAL.)

it was very difficult to determine how far they might be carried under such conditions, owing to the small size of the rooms where the experiment was tried, it was possible in a few cases to secure specimens which had drifted from 20 to 30 feet from the fan. This led to an attempt to test the matter under outdoor conditions.

Arrangements were made with Mr. L. H. Worthley, then assistant forester of Massachusetts, whereby the tests would be made cooperatively with the department which he represented. Supplies and assistance were furnished by the State, and several men employed by the Bureau of Entomology attended to certain parts of the work. Many valuable suggestions were secured from Mr. Worthley, and from Messrs. D. M. Rogers and W. F. Fiske of this bureau. In carrying on the tests especial credit is due to Mr. C. W. Collins, who assisted in many of the experiments; to Messrs E. A. Proctor, J. V. Schaffner, and K. W. Brown for assistance and suggestions; to Mr. H. R. Gooch, who constructed the screens and apparatus used; to Messrs. C. W. Stockwell, F. H. Mosher, and John E. Dudley, jr., for helpful suggestions and for recording data on several phases of the work; and to Messrs. H. S. Barber, Melvin Guptill, H. A. Preston, and W. N. Dovener, who prepared the photographs and accompanying illustrations. Suggestions which had a practical bearing upon the tests were made by those mentioned and by many others connected with the work at the parasite laboratory, so that all have contributed to the results which will be given.

For the weather conditions in Massachusetts we are indebted to Mr. J. W. Smith, district forecaster of the Weather Bureau, United States Department of Agriculture, at the Boston office. Data have also been secured from local forecaster Edward P. Jones, at Portland, Me., and from local forecaster E. C. Vose, at Concord, N. H., who have very courteously allowed the records of their offices to be freely used.

Plans were made to carry on several experiments out of doors as soon as the caterpillars began to hatch, and for this purpose a number of favorably situated localities were selected. In each case a screen of galvanized-iron wire was attached to a wooden frame, and after the netting had been treated with a thin application of tree tanglefoot it was set up so that caterpillars were likely to drift upon it if carried by the prevailing wind.

EXPERIMENTS AT LINCOLN, MASS.

The first trap was placed on a raft (Pl. VI) which was moored near the center of Sandy Pond, Lincoln, Mass. Two screens, each 12 feet long and 6 feet high, were placed at right angles so as to form a cross. The screen used was ordinary poultry wire having a mesh about 1 inch in diameter. The woodland surrounding this pond was

moderately to badly infested with the gipsy moth, and it was expected that if the young caterpillars were carried by air currents it would be possible to secure some of them in the tanglefoot which was applied to the wire netting. The pond is about a mile and a half long and three-fourths of a mile wide. As there are two small islands on which brush and sprouts were growing near the west side, an attempt was made to anchor the raft as nearly as possible at a point midway between the islands and the opposite shore. The raft was constructed April 25, 1910, and an attempt was then made to anchor it in the center of the pond. Owing to the high wind it was found impossible to do so, therefore it was anchored near one of the small islands, where it remained until May 2, when the anchorage was changed to the center of the pond. On this date the screens were examined, but no larvæ were found in the tanglefoot.

On May 9 the pond was visited, and it was found that the raft had drifted from its anchorage to the shore at the northeastern end of the pond. Infested woodland was present within 200 yards of where the raft lodged. The tanglefoot was examined, but no caterpillars were found. Owing to the strong wind it was impossible to tow the raft to the center of the pond, so it was allowed to remain where it was found.

On June 9 a visit was made to this trap for the purpose of making the final examination and dismantling it. A single caterpillar was found in the tanglefoot, which proved upon a careful examination to be a first-stage gipsy-moth larva. Owing to the difficulty of thoroughly examining the wire screen, because some of the tanglefoot had become rather hard and also because of the presence of an innumerable number of Micro-Diptera and other small insects, the screen was taken from the wooden form and brought to the laboratory, where later in the season it was cut up into small strips and thoroughly examined. This work was done by Mr. J. V. Schaffner and Mr. Emery Proctor, but no other gipsy-moth caterpillars were found upon it. During the first part of the experiment the weather was cool, which probably resulted in the young larvæ moving about but little, and this may explain why more caterpillars were not caught in the trap. Attention should be called to the small area of screen which was exposed, and in the light of future experiments it does not appear strange that no more caterpillars were secured.

EXPERIMENTS IN LYNN WOODS, MASS.

It did not seem practical, however, when the experiment was planned, to attempt to settle the question by making one test. Several other screens were constructed, and one made in a similar manner to the one used on the raft at Lincoln was placed on top of an obser-

vation tower at Mount Gilead in the Lynn Woods. (Pl. VII.) The arms on these screens were 10 feet long and 4 feet high. The trap was placed at the top of a tower 50 feet from the ground and fully 25 feet above the tops of the tallest trees. A few caterpillars were feeding on April 29, the date when the trap was installed.

The object of this experiment was to determine, if possible, whether caterpillars could be caught high in the air. The woodland surrounding this tower was badly infested, and later in the season a considerable area was completely stripped of foliage. On May 4 the trap was examined, but no caterpillars could be found. A large percentage of the gipsy-moth caterpillars had hatched, but most of the larvæ were still on the egg clusters, although some were feeding. The weather was cool, and only a slight wind was blowing.

The trap was examined on May 7, 11, 16, and 17, but no caterpillars could be found. On May 28 another examination was made with the same result. In woodland the caterpillars were now in the second, third, and a few in the fourth stage. The weather was cool, and very few were spinning down from the trees. On June 7 another examination was made, and on the 13th the screen was moved and brought to the laboratory, where it was examined later in the season by Messrs. Proctor and Schaffner, but no gipsy-moth caterpillars were found.

EXPERIMENTS AT CLIFTONDALE, MASS.

Another experiment was conducted near Cliftondale, Mass. Permission was secured to drop wire screens, which had been tanglefooted, from the sides of a high water tower (Pl. VIII) at the old Saugus race track, which borders a large area of salt marshes. These screens were manipulated with ropes and pulleys in such a way that they could be raised and lowered in order to make examinations. On one side of the tower, to the eastward, no trees were growing for a distance of about 2 miles, and the nearest trees in any direction, except for a few willow sprouts growing along the edge of the race track which will be mentioned later, were a quarter of a mile distant.

Two screens, 34 feet long and 6 feet wide, were dropped from the east side of the tower, while another screen of the same dimensions was suspended on the west side. They were placed in position April 30, 1910, and were examined at intervals until the middle of June. On May 11, a single gipsy-moth caterpillar was found on one of the screens on the east side of the tower, 25 feet from the ground. On May 18 a stock of newly hatched gipsy-moth caterpillars was liberated in the marsh 1,500 feet south of the tower at several stations, the idea being to give an opportunity for the larvæ to be carried by the wind to the tanglefoot screens. No caterpillars were found

on the screens as a result of this liberation. When the experiments were started it was planned to examine thoroughly a few willow sprouts, which were growing along the race track not far from the water tower, but on account of the pressure of other work this was neglected. In making an examination of the screens May 28 it was found that several old egg clusters and a considerable number of caterpillars were present on a clump of willow sprouts about 25 feet from the screen on the west side of the tower. In spite of this, however, no caterpillars were found on this screen during the season. There is a bare possibility that the caterpillar found on the screen on the opposite side of the tower may have come from some of these willow sprouts, but it is doubtful whether this is the case. The screens were removed June 13 and examined at the laboratory in the same manner as those already mentioned, but no other caterpillars were found.

The foregoing experiments were carried on under natural conditions and on a large scale, and in addition two other tests were made by Mr. Mosher. One large screen was built in the form of a cross, the same as the one placed on the tower at Mount Gilead. It was set up on land at Manchester, Mass., where the forest had recently been cut. Large trees surrounding this area were badly infested with the gipsy moth, and some additional data would probably have been secured from this experiment if a forest fire had not run through the area where it was conducted.

Another raft was constructed at Chebacco Lake in Essex, Mass., similar to the one used at Sandy Pond, but owing to bad weather and high winds it was impossible to anchor it securely in the center of the lake until it was too late to secure the data desired in the experiment. Before these tests had been carried very far it appeared desirable to check up the results in a more definite way, and in order to do this a series of experiments were planned, which were carried on by Mr. C. W. Collins and the writer on the salt marshes (Pl. IX) between Lynn and Revere, Mass.

EXPERIMENTS ON LYNN MARSHES, MASS.

A box of egg clusters containing many newly hatched larvæ was attached to the top of a pole about 6 feet from the ground. This point was used as a central station and was half a mile or more from any tree or tree growth. One end of the box (Pl. IX, fig. 1), containing the egg clusters and caterpillars, was partly cut away with a knife, while in the other a small hole was made to allow the wind to blow through the box. Small screens, 2 feet wide and 6 to 8 feet long (Pl. X), were attached to stakes which were sharpened so that they could be pressed into the ground; so that when these screens were set up they were about 5 feet above the ground. They were

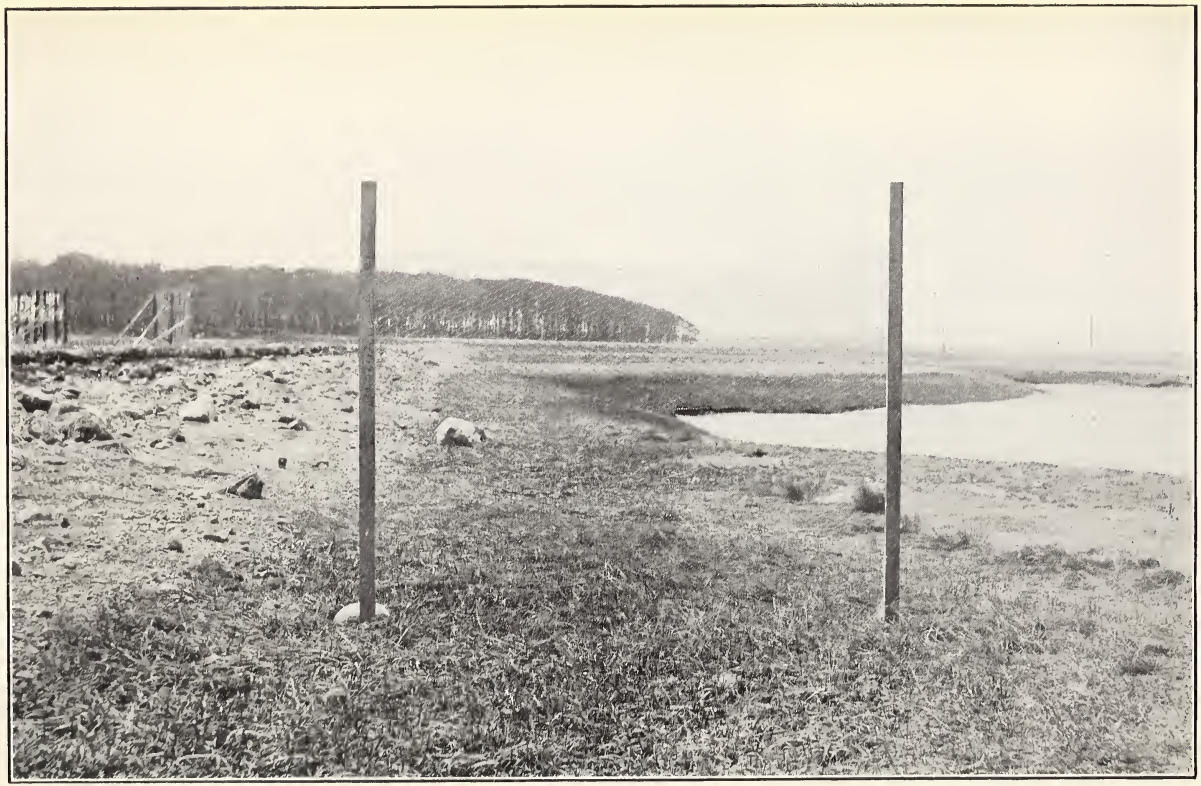
TRAP BUILT ON TOP OF OBSERVATION TOWER TO TEST AVIATION OF GIPSY-MOTH LARVÆ. (ORIGINAL.)

SCREENS TREATED WITH TANGLEFOOT ATTACHED TO WATER TOWER TO TEST AVIATION OF GIPSY-MOTH LARVÆ. (ORIGINAL.)

[The screen on the left-hand side is not visible in the illustration.]

VIEW OF SALT MARSHES NEAR LYNN, MASS., WHERE EXPERIMENTS ON AVIATION OF CATERPILLARS WERE CONDUCTED.
Note that the land is level and treeless.

POST AND BOX USED IN EXPERIMENTS.
The newly hatched caterpillars spun down from the open flap of the box and were blown away by the wind. (Original.)



PORTABLE SCREENS USED FOR CATERPILLAR-AVIATION EXPERIMENTS.

Trees at Oak Island, Revere, Mass., in the background. (Original.)

covered with tanglefoot and were placed in the direction toward which the wind was blowing, the idea being that if the caterpillars were blown from the box which was set up at the central station, specimens might be caught on the screens. Owing to the variability of the air currents and the continued changes in the direction of the wind it was found better to use three screens, which were set up at distances ranging from 50 to several hundred feet from each other, but all at an equal distance from a central station. On May 6 a single screen was set up 50 feet from the central station. The wind was light and variable, but 10 minutes after it had been placed in position a caterpillar was caught. At the expiration of an hour five caterpillars were found on the screen.

It was then set up 100 feet from the central station. Four caterpillars were caught in a short time. On the following day two extra screens were made in order to provide for changes in the direction of the wind. During the day two caterpillars were caught at 150 feet, two at 200 feet, one at 250 feet, and one at 300 feet. On May 10 one caterpillar was caught at a distance of 350 feet from the central station, after the screen had been exposed for 3½ hours. On May 11 one caterpillar was caught 500 feet from the central station, after this screen had been exposed for about an hour. The screens were then put up 600 feet from the station, and 30 minutes later two caterpillars had been caught. Two of the screens were then set up 700 feet from the station and remained there until late in the afternoon. Before leaving for the night the remaining screen was set up in the direction of the prevailing wind and at a distance, which later proved to be 1,833 feet, from the central station. On the following morning a caterpillar was found on the last-mentioned screen. The supply of first-stage caterpillars being practically exhausted on this date, we were obliged to discontinue these experiments, but the screens were removed to another point on the marsh and set up at measured distances of one-fourth mile, 1,800 feet, 2,300 feet, and 2,800 feet north of Oak Island, Revere, Mass. This is a wooded island (Pl. X) of several acres surrounded by salt marsh; the trees are generally infested with the gipsy moth, and owing to its proximity to the ocean the growth of the larvæ is considerably retarded. It was hoped that evidence might be secured that caterpillars were carried by the wind from this locality, but no larvæ were caught on the screens, although they remained in position until June 13.

In connection with these experiments it should be said that practically the whole of this salt-marsh area (Pl. IX) is flooded at high tide; hence it was possible to carry on the experiments during only a part of the day. The weather during April was cool, which is usually the case in this region near the seacoast, where the land is flat and exposed to strong air currents. The gipsy-moth caterpillars are not

very active unless the weather is warm, and when the experiments were conducted on cool days it was necessary to strike the box in which the egg clusters and caterpillars were confined in order to jar more of the larvæ from the open end and induce them to spin down toward the ground. If a strong wind was blowing at the time, they would be caught up and blown away, and occasionally it was possible to see them drift 20 or 30 feet before they passed from view. Table I gives a summary of the data secured in these experiments.

TABLE I.—*Direction and velocity of wind, at Lynn Marshes, Mass., May 6 to 12, 1910.*

Date.	Screens.		Wind.		Average temperature.	Number of larvæ caught.
	No.	Distance from station.	Direction.	Average velocity.		
1910.		*Feet.*		*Miles per hour.*	°*F.*	
May 6	1	50	NW.	11	60	5
Do	1	100	NW.	11	61	4
May 7	3	150	SW.	14 to 17	66 to 70	2
Do	3	200	SW.	14 to 17	66 to 70	2
Do	3	250	SW.	14 to 17	66 to 70	1
Do	3	300	SW.	14 to 17	66 to 70	1
May 10	3	350	SW.	18 to 23	63 to 67	1
May 11	3	500	SW.	15	63	1
Do	3	600	SW.	15	66	2
May 12	2	700	W.			0
Do	1	1,833	W.	7 to 19	51 to 66	1

The temperature records and velocity of the winds were secured through the courtesy of the United States Weather Bureau at Boston.

The notes that were kept on the marshes show that the direction of the wind varied slightly from the Weather Bureau records, and the former are given above. In other respects there were probably minor differences, but they would not affect the result to any great extent. It should be noted, however, that on none of the days mentioned did the wind maintain a velocity which was at all constant, and changes in direction were sudden and variable. This added to the difficulty in carrying on the experiments and made it necessary to change repeatedly the location of the screens. The most data were secured on May 7, and, by referring to the table, it will be noted that the weather was warmer than on any of the other days when tests were made; also the direction of the wind was more constant.

These experiments indicate that the best opportunity for the dispersion of gipsy-moth caterpillars by the wind is when the temperature is above 65° and the velocity of the wind over 15 miles an hour. They further show that the young larvæ of this insect can be carried by the wind a third of a mile from a point less than 6 feet above the ground. This being the case, there is an opportunity for extensive natural spread by the wind. It is not necessary for the velocity of the wind to remain constant, as there is doubtless much dispersion

during sudden squalls or sharp whirlwinds, provided the temperature is high enough to cause the caterpillars to become active. Early in the spring it is quite common to see papers or leaves caught up by such winds and carried several hundred feet in the air. This often results in these objects coming in contact with strong currents high above the earth and being carried many miles before falling. Undoubtedly the same thing happens when caterpillars are suspended from the trees by the silk which they spin, although absolute proof of this point is very difficult to secure. Several other elements have an important bearing on this matter, such as the density of infestation and the quantity of silk which is produced by the first-stage larvæ.

QUANTITY OF SILK PRODUCED BY FIRST-STAGE GIPSY-MOTH LARVÆ.

A record is given on page 331 of the report on the gipsy moth, by Messrs. Forbush and Fernald, of the quantity of silk produced by first-stage gipsy-moth larvæ. The data were secured by inducing the larvæ to commence spinning, after which the end of the thread was attached to a reel, and the quantity produced was determined by multiplying the circumference by the number of revolutions which it was turned. In these experiments newly hatched caterpillars produced the following quantities of silk: 4 feet 6 inches, 9 feet 7 inches, 38 feet 2 inches, and 69 feet 4 inches. Older first-stage caterpillars spun: 53 feet 2 inches, 24 feet 2 inches, 3 feet 2 inches, 6 feet 4 inches, 7 feet, 25 feet 3 inches, and 22 feet 6 inches. The record indicates that some of the caterpillars could not be induced to spin, but from the figures given the quantity of silk spun by newly hatched first-stage caterpillars ranged from 4 feet 6 inches to 69 feet 4 inches, giving an average of 30 feet 3 inches, while for caterpillars in the same stage that were a little older the record was from 3 feet 2 inches to 53 feet 2 inches, giving an average of 23 feet 8 inches.

These experiments were repeated in the spring of 1911. An attempt was made to use a reel similar to the one already mentioned, but much difficulty was experienced, even when the larvæ were placed in warm sunshine and when spinning was encouraged by using an electric fan to make a strong air current. It was found that no spinning would take place when the temperature was low. Unless the larvæ were constantly disturbed, they would climb up the threads which they had spun, and after this commenced it was difficult to induce them to spin more or to prevent them from crawling up to the attachment on the reel. The same thing occurs in nature, and it is quite common to find first-stage caterpillars suspended from the trees bearing a small mass of white material beneath the mouth cavity or partly around the first pair of legs. Close examina-

tion will show that this consists of silk which the larva has spun, and it is probable that this adds to the buoyancy of the insect if it is caught up by the wind.

As the method of using the reel gave very poor results, two sets of experiments were carried on by Mr. C. W. Stockwell in the laboratory. He induced the caterpillars to spin, and attached the thread to the end of a stick 1 yard long. As the insect lowered itself, the thread was measured with the stick by raising and inverting it, and thus the larva was prevented from spinning to the floor of the room. In the first set records were secured from 18 newly hatched larvæ that had not fed. The quantity of silk spun ranged from 7 feet 6 inches to 25 feet 6 inches, averaging 17 feet. Fourteen records were then secured from larvæ 3 days old, and the silk ranged from 12 feet to 63 feet 5 inches, with an average of 31 feet.

The results of these tests show that there is much individual variation in the quantity of silk that caterpillars will spin, and it is probable that under favorable outdoor conditions much more would be produced than is indicated by the averages given.

If 20 to 30 feet of silk is spun by a larva it will undoubtedly help it to remain in the air in case the thread is broken by the wind, and will probably add buoyancy to the insect and thus increase the distance that would ordinarily be covered by wind spread.

RELATION OF TEMPERATURE TO HATCHING OF EGGS.

Temperature has a very important relation to the hatching of insect eggs; hence the time of larval appearance varies from year to year. Gipsy-moth eggs begin to hatch the last week in April, but the hatching is often deferred a week or more. Owing to the warm weather in March, 1910, hatching took place in the field as early as April 3, but the bulk of the eggs did not hatch until much later. In the case of the gipsy moth—and the same principle governs in the case of other insects which winter in the egg form—it is possible to secure hatching in the winter if the eggs are kept in a warm room. The length of the period of high temperature which is required to hatch them varies with the season of the year. For example, gipsy-moth eggs collected late in December and kept at a temperature of from 70° F. to 80° F. will hatch in about 15 days, while if the same collection is made in March hatching will take place in about half the time. This shows that as the normal time for hatching approaches it requires a shorter period of warm weather to bring out the larvæ.

During the past four years the first date of finding gipsy-moth larvæ in the field in Massachusetts was, in 1908, April 22; 1909, April 22; 1910, April 3; 1911, April 28. The data for 1908 were furnished by Mr. W. F. Fiske. The other dates were secured from field reports

made to Mr. D. M. Rogers. The hatching thus recorded took place in localities which became warm very early in the spring, but this serves as a basis for comparing the temperatures.

The entire period of hatching usually extends over a month. In fact, in some parts of the infested territory where the summer season is short, owing to the high altitude or to the northern latitude, the period is considerably longer.

Mr. Henry L. McIntyre, one of the general foremen in charge of moth work for the Bureau of Entomology, informs me that several unhatched gipsy-moth egg clusters were found July 1, 1910, at Winchendon, Mass., by scouts who were working under his direction. The clusters were well formed and were apparently fertile, although this point was not fully determined.

He also reports that in the spring of 1908 he found egg masses in maple swamps near Portsmouth, N. H., that had not hatched on June 15. In 1909 he observed several egg clusters that had just hatched in a stone wall at Gilford, N. H., on June 4.

This shows the variation in time of hatching in different localities and situations, but it is exceptional for hatching to take place after June 1. Additional data on the dates of hatching have been furnished by Mr. F. A. Bates, who has for many years been prominently connected with moth work, and from various other careful observers.

The accompanying diagram (fig. 1) shows the range in temperatures for 20 days preceding and 10 days following the first report of hatching for the years 1908 to 1911. It will be noted that in 1910, when hatching was recorded April 3, nearly two weeks of warm weather immediately preceded hatching. In 1909 the warm weather was interrupted by several cold days, while in 1908 and 1911 hatching took place during the only warm period that occurred in the month. This last record shows the tendency of the eggs to hatch at the first opportunity as the season grows late.

EFFECT OF TEMPERATURE ON ACTIVITY OF LARVÆ.

As the activity of the caterpillars after hatching as well as their emergence from the eggs depends upon the temperature, several experiments were made to determine the temperature at which the larvæ are most active, since it is obvious that little distribution by wind would be possible unless the larvæ were active during the first stage. Accordingly, a series of laboratory tests were made by Mr. Collins. For this purpose a constant-temperature incubator was used, it being arranged in such a way that the thermostat which regulated the heat supplied by electric incandescent lamps could be changed without opening the incubator.

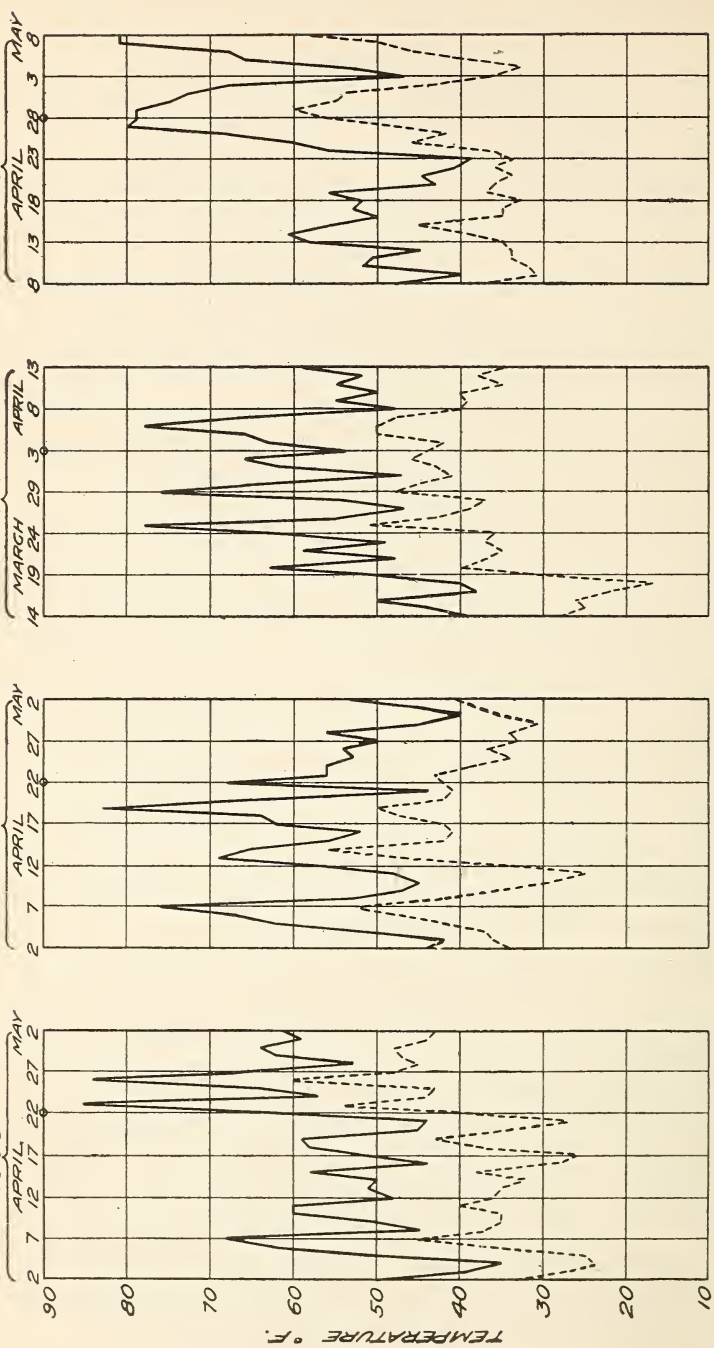


FIG. 1.—Diagram showing maximum and minimum temperature before and after hatching of eggs of the gipsy moth, 1908–1911. (Original.)

LABORATORY EXPERIMENTS.

On May 3, 1911, 1,500 gipsy-moth caterpillars, 12 hours old or less, were placed in a glass battery jar, which in turn was placed for a short time in the laboratory yard where the temperature was 46° F. There was no activity, and later, when the jar was placed in the basement where the temperature was 48° to 50° F., the same result was observed. The jar was then placed in the incubator and the following notes were made by Mr. Collins:

The temperature was held at degrees mentioned for from 10 to 20 minutes.

52° F. No motion unless larvæ were disturbed; then it was very slight.

54° F. No motion in mass of larvæ. Two crawled 5 inches.

56° F. No motion in mass of larvæ.

58° F. No motion in mass of larvæ. Two have crawled 1 inch in 10 minutes.

60° F. No motion in mass of larvæ. Two have crawled 6 inches; two, 4 inches.

62° F. No motion in mass of larvæ. Fifteen larvæ crawling. One climbing up thread that had been spun. One spun 1 inch and crawled up. One spun ½ inch.

64° F. Motion in mass noticeable. Fifty larvæ crawled actively, a few spinning.

66° F. Motion in mass more noticeable. One hundred larvæ crawling, a few spinning short threads.

68° F. Mass of larvæ active. Eight larvæ have each spun 7½ inches.

70° F. Almost every larva moving.

72° F. Caterpillars all crawling about and spreading freely.

74° F. Many spinning and hanging by threads.

76° F. Larvæ very active and spinning.

78° F. Half of the larvæ have crawled from jar. All active. They spin rapidly.

80° F. Active and spinning freely.

84° F. About the same as 80° F.

88° F. Possibly a little more active.

92° F. Larvæ crawling and spinning more rapidly.

96° F. All caterpillars have left the jar and are on the move. It took this temperature to force all of them from the jar.

100° F. Larvæ very active. They crawl very fast, but spin little.

106° F. Same as 100° F.

108° F. Larvæ gathered in masses; less crawling and spinning.

110° F. Little crawling; larvæ squirming in the masses.

After holding the temperature for two hours at 110° F. the incubator was cooled down to 82° F. Twenty-five dead larvæ were found, and the remainder were not very active. The temperature was then raised again to 110° F. At 92° F. larvæ became more active, and this continued until 100° F. was reached. Most of them showed the effects of the previous high temperature.

A set of observations was also made May 3, 1911, on first-stage caterpillars which hatched April 22 and were feeding in trays at the laboratory. No motion was noted at 54° F., but when the temperature rose to 62° F. they crawled slowly about on the food. At 68° F. they were crawling freely, and activity increased as the temperature rose.

On May 6 a large tray of caterpillars was placed in a room in direct sunlight and the temperature rose to 100° F. This resulted in abnormal activity, and many of the larvæ spun a considerable quantity of silk.

In order to check these experiments, Mr. Collins made a series of field observations in woodland in Melrose, Saugus, and Reading.

FIELD OBSERVATIONS.

May 13, 1911, visited woods east of the laboratory at Melrose Highlands, which had been badly infested and partially to wholly defoliated in 1909 and 1910. Infestation not as bad this year. At 9.30 a. m. the temperature in the sun was 92° F.; in the shade, 84° F.

All eggs have apparently hatched, and the caterpillars are in the first stage. There is plenty of foliage. Very little spinning was observed. In the afternoon of the same day visited badly infested woods in Saugus. Temperature, 96° F. in sun; 84° F. in shade. A strong wind was blowing, which varied from northwest to southwest. First-stage caterpillars were spinning some. If a branch was shaken, they would spin down and be blown away.

On the following day observations were made at Reading, Mass. The temperature ranged from 85° F. in the sun to 79° F. in the shade; the wind was west and southwest, but rather cool. First-stage caterpillars were feeding steadily and spinning freely. Twenty very small first-stage larvæ and two that were nearly ready to molt were observed spinning down from a white-oak tree. Threads from 2 to 4 feet long were noted, but it was very difficult to determine the quantity of silk spun, as it is almost invisible. A considerable quantity of silk was noticed among the small twigs and branches on this tree, therefore it is evident that frequent spinning had been attempted by the larvæ.

Although few field observations were made to determine the temperature at which gipsy-moth caterpillars are active, it is evident that the results do not vary greatly from those carried on in the laboratory. Experiments show that there is practically no activity when the temperature is below 60° F., and that only a part of the caterpillars move about at 65° F. Above this point activity increases rapidly.

RELATION OF ACTIVITY TO THE SPINNING OF SILK.

The above experiments show that the activity of the caterpillars is governed by the temperature, and it is obvious that the spinning of silk depends largely upon the activity of the larvæ, and hence upon the temperature. There are other factors, however, that enter into the problem, and these must be considered with the element of temperature. They are:

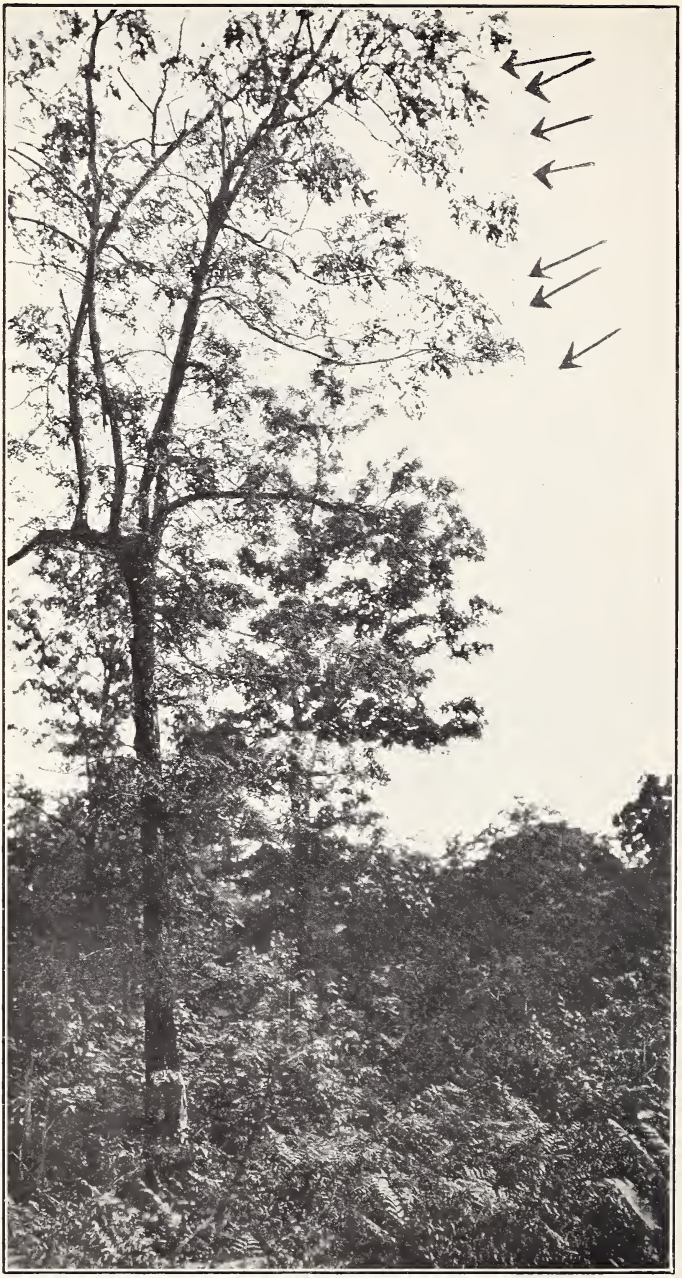
Location where eggs are deposited.
Degree of infestation.
Kind of food plants.
Condition of food plants.
Direction and character of the wind.

LOCATIONS WHERE EGG CLUSTERS ARE DEPOSITED.

The egg clusters of the gipsy moth are not always deposited on the plant which furnishes the food for the previous generation. In fact, when the caterpillars are nearly ready to transform they usually

FIG. 1.—FEMALE GIPSY MOTHS DEPOSITING EGG CLUSTERS ON WHITE-OAK TREE NEAR THE GROUND. (ORIGINAL.)

FIG. 2.—EGG CLUSTERS ON STONE WALL. LOCATION OF CLUSTERS INDICATED BY ARROW. (ORIGINAL.)



OAK TREE SHOWING GIPSY-MOTH CATERPILLERS SPINNING TO THE GROUND. POSITION OF LARVÆ INDICATED BY ARROWS.

Note that the tree is partially defoliated. (Original.)

SOLID WHITE-PINE BLOCK NEAR NASHUA, N. H.

Small trees in foreground were transplanted some years ago. The foliage of this species is not attacked by *small* gipsy-moth larvæ, so it is not injured if grown in clean stands. (Original.)

seek places which are protected from the sun, and in such situations pupation takes place. The egg masses are deposited near the cases from which the females emerged. Hence it is seldom possible to find egg clusters on the upper sides of the branches or twigs of trees, because the lower sides furnish more protection and they are sought by the caterpillars before pupating. For this same reason it is usually possible to find many egg clusters on tree trunks just above the ground (Pl. XI, fig. 1), especially if there is grass or other material which would furnish protection. Many larvæ, however, crawl from the trees and seek secluded places, sometimes at a considerable distance from their food plants, and rubbish piles, stone walls (Pl. XI, fig. 2), lumber piles (Pl. III), outbuildings, or other protected places are often found badly infested with egg clusters.

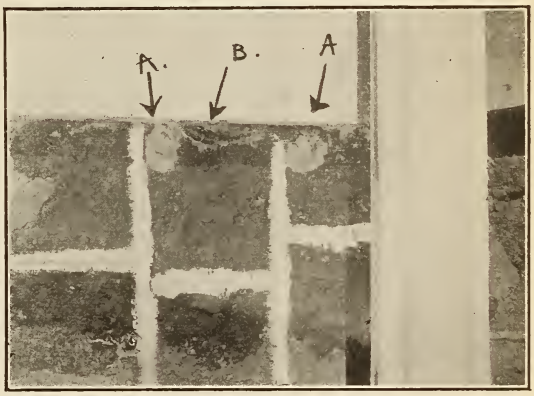


FIG. 2.—Female pupal case and egg clusters of gipsy moth on stone foundation under woodwork of house. Arrows *A* indicate location of egg clusters; arrow *B* indicates location of pupal case. (Original.)

The larvæ which hatch in such situations must of necessity find suitable food if they are to survive, and the more traveling it is necessary for them to do to accomplish this purpose the greater chance there is that dispersion by the wind will take place. For instance, egg clusters are frequently deposited beneath porches or on the underpinning of houses (fig. 2), where it is impossible to destroy them without first removing a part of the building. After hatching takes place the larvæ can commonly be found wandering about in search of food. They often crawl to the roofs of the buildings, and if they spin down from such a location, which often happens, there is ample opportunity for dispersion by the wind.

As a rule the location of the egg clusters and the distance that the larvæ have to travel for food are important factors, because hunger causes them to search for food, and activity is essential to dispersion.

DISTANCE FIRST-STAGE LARVÆ CAN CRAWL.

It is important to know how far first-stage larvæ can crawl, as upon this factor depends the chance for the establishment of many new colonies. Experiments reported by Forbush and Fernald show that newly hatched larvæ have crawled from 36 to 144 feet before

dying. The tests were carried on under laboratory conditions which were unfavorable to the insects.

During the winter of 1911–12 a few experiments of the same sort were tried at the gipsy-moth parasite laboratory, and records ranging from 31 to 138 feet have been secured. The conditions for making the tests were very unsatisfactory, and it is probable that newly hatched larvæ, without food, would be able to crawl, on the average, about 100 feet in the open before death would ensue. This does not give the maximum distance that the majority of larvæ could crawl, because many of them in going that distance would find some foliage which could be eaten and thus would be enabled to proceed farther.

DEGREE OF INFESTATION.

The degree of infestation has an important bearing on dispersion. When only a few egg clusters are present on a tree the larvæ have plenty of food, and it is not necessary for them to move about so actively. As the infestation increases the feeding conditions become more crowded, and, as a result, the larvæ are disturbed and large numbers of them spin to the ground. In badly infested places the air is sometimes well filled with a network of silken threads, which are made by larvæ spinning to the ground (Pl. XII), and it is possible to see large numbers of them hanging from the trees.

These conditions favor dispersion by the wind.

KINDS OF FOOD PLANTS.

At the time the gipsy moth first became noticeable in this country and caused so much damage, it seemed almost impossible to find plants upon which it would not feed. Many experiments were carried on with fifth and sixth stage caterpillars, which were fed in glass jars upon various kinds of foliage, and very few plants were rejected, especially if the insects were supplied with no other food. The results of these experiments were published by Forbush and Fernald in 1896. Since that time it has become gradually more noticeable that the larvæ show marked preference for certain species of trees. This may be due to a gradual change of habit, or to the fact that caterpillars which do not find food which is most suitable, although they may strip and injure the tree, may not come through to maturity.

There is considerable difference in food requirements of the small and the large caterpillars of this insect, the former not being able to survive on some species of trees upon which the larger ones will feed. The white pine is one of the trees of which this may be said, and it has been repeatedly demonstrated that the first-stage larvæ can

not live upon this tree. This being the case, dispersion by the wind, which is concerned chiefly with small caterpillars, is limited in its results by the food plants which the young caterpillars are able to reach, and this depends somewhat upon the ability of the larvæ to crawl. For instance, if caterpillars are blown by the wind and drop on cultivated ground or in pastures, they must perish on account of scarcity of food. Similarly, if caterpillars lodge in solid pine forests (Pl. XIII) they will perish for want of suitable food. In fact, the establishment of the pest in this way depends upon the larvæ being able to find suitable food. Either the larvæ must be dropped by the wind on a food plant that is favorable for their development or they must fall within crawling distance of it. In many sections of the country the foliage is unfavorable for gipsy-moth food; hence colonies have not become established.

CONDITION OF FOOD PLANTS.

The condition of the trees in an infested area has an important relation to the liability of the spread of the insect. Unfavorable food, coupled with warm weather, naturally stimulates the activity of the larvæ, and this increases the chances for spread. If there are dead trees in the infested area the chances of wind spread of the larvæ from them are greater than on healthy trees, as the caterpillars are unprotected from the sun and wind and move about continually in search of food if the temperature is high enough.

DIRECTION AND VELOCITY OF THE WIND.

Of all of the factors thus far enumerated perhaps no one is as important with regard to dispersion as is the wind. The others may be regulated or controlled to some extent but it is impossible to do this with the wind. For instance, it is possible to reduce the infestation in any area so that wind spread is nearly precluded, because it is dependent upon the factors which have been mentioned, which, with the exception of temperature, can be controlled.

The natural trend of dispersion of the gipsy moth has been toward the north and northeast. The spread of the brown-tail moth has been chiefly in a northeasterly direction, and the reason attributed to this has been that the prevailing wind during July, when the moths are flying, was from the opposite direction. Since the aviation of first-stage gipsy-moth larvæ has been proved, it is evident that a part, at least, of the more newly infested area is due to the action of the wind. It is also true that the prevailing winds in April and May, when the larvæ are small enough to be distributed in this way, is chiefly from the south and southwest. Table II gives the record of wind direction for 20 days in April and May, when the temperature

was highest, during the years 1902 to 1911. Table III shows the wind direction during the same number of days for the lowest of the maximum temperatures.

TABLE II.—*Direction of wind during 20 days of highest temperature in April and May, 1902–1911. (From records of the United States Weather Bureau at Boston, Mass.)*

Date.	Temperature.	Direction of wind.	Date.	Temperature.	Direction of wind.
	°F.			°F.	
Apr. 22, 1908	85	SW.	May 22, 1911	92	W.
Apr. 26, 1908	84	SW.	May 23, 1902	88	SW.
Apr. 29, 1903	83	W., NW.	May 18, 1903	88	W.
Apr. 30, 1903	83	S.	May 19, 1903	88	SW.
Apr. 19, 1909	83	SW.	May 27, 1908	88	SW.
Apr. 27, 1911	80	W.	May 29, 1911	88	SW.
Apr. 28, 1911	79	W.	May 26, 1904	87	SW.
Apr. 29, 1911	79	NW., SE.	May 26, 1908	87	SW.
Apr. 6, 1910	78	SW.	May 21, 1911	87	SW
Apr. 7, 1909	76	SW.	May 19, 1906	86	W.
Apr. 29, 1902	75	S., W.	May 31, 1908	86	SW.
Apr. 30, 1911	75	SW.	May 24, 1910	86	SW.
Apr. 26, 1905	74	W.	May 28, 1911	86	SW.
Apr. 30, 1907	73	SW.	May 24, 1904	85	SW.
Apr. 15, 1910	73	NW.	May 11, 1911	85	SW.
Apr. 21, 1905	72	SW.	May 24, 1902	84	SW.
Apr. 30, 1905	72	W.	May 17, 1903	84	SW.
Apr. 6, 1911	72	W.	May 21, 1903	84	SW., NW.
Apr. 23, 1902	71	E., SW.	May 22, 1903	84	NW.
Apr. 28, 1902	71	W.	May 12, 1908	84	SW.

TABLE III.—*Direction of wind during 20 days of lowest temperature in April and May, 1902–1911. (From records of the United States Weather Bureau at Boston, Mass.)*

Date.	Temperature.	Direction of wind.	Date.	Temperature.	Direction of wind.
	°F.			°F.	
Apr. 4, 1908	35	NW.	May 2, 1903	44	E., SE.
Apr. 2, 1911	35	W.	May 3, 1907	44	E.
Apr. 7, 1907	36	E.	May 1, 1909	45	NE.
Apr. 5, 1903	37	NW.	May 7, 1908	46	E.
Apr. 20, 1904	38	N., W.	May 3, 1903	47	E.
Apr. 2, 1906	38	N.	May 17, 1905	47	NE.
Apr. 8, 1907	38	E.	May 22, 1909	47	NE.
Apr. 9, 1907	39	N.	May 5, 1910	47	N.
Apr. 10, 1910	39	W.	May 3, 1911	47	W.
Apr. 3, 1908	39	W., NW.	May 28, 1906	48	NE.
Apr. 4, 1911	39	SE.	May 2, 1907	49	NE.
Apr. 23, 1911	39	NE.	May 4, 1907	49	SE.
Apr. 16, 1903	40	NE.	May 7, 1907	49	E.
Apr. 16, 1904	40	NW.	May 27, 1907	49	E.
Apr. 2, 1907	40	N.	May 8, 1908	49	NE.
Apr. 30, 1909	40	NE.	May 4, 1910	49	NE.
Apr. 1, 1911	40	W.	May 3, 1902	50	NE.
Apr. 9, 1911	40	N.	May 15, 1904	50	NE.
Apr. 10, 1902	41	N.	May 16, 1905	50	N., NE.
Apr. 9, 1906	41	SE.	May 11, 1906	50	W.

A glance at these tables indicates that in April, when the temperature ranged above 70°, 16 days out of 20 the wind varied between south and west. For the same month during the low temperatures the wind ranged between north and east for 10 days out of the 20. Corresponding figures during May show that for 18 days out of 20 the wind was from the south and west, and for 16 days out of 20

the wind was from north to east. For the years mentioned, when there were bad woodland infestations in Massachusetts, the wind during the hot days was usually southwest, which would be most favorable for the spread of the insect into the region where it has since been found in scattered colonies.

The relation of temperature and the direction and velocity of the wind are intimate, as shown by the tables which follow.

It has been stated that wind spread is possible when the temperature as recorded by the Weather Bureau is as low as 65°, but an increase in temperature makes the chances of spreading greater. Tables IV and V give the direction of the wind for the different years, at the Boston Weather Bureau station when the temperature was 65° or higher, and the wind velocity 10 miles per hour or more.

In all cases where the temperature is 70° F. or above, italic letters and figures are used in the columns of the table giving the temperature and the direction and velocity of the wind. Otherwise the letters and figures are in Roman.

TABLE IV.—*Temperature and direction and velocity of wind on dates after hatching of gipsy-moth caterpillars, 1902–1911.*

(Data from U. S. Weather Bureau at Boston, Mass.)

Date.	24 hours.	Maximum temperature.	Direction of wind.	Velocity of wind.	Date.	24 hours.	Maximum temperature.	Direction of wind.	Velocity of wind.
1902.		°F.		*Miles per hour.*	1902.		°F.		*Miles per hour.*
Apr. 21	AM	65	W	12	May 16	AM, PM	*72*	*W*	*20*
23	PM, AM	*71*	*W*	*29*	17	AM	*70*	*N*	*18*
24	AM	66	W	26	18	AM, PM	*78*	*NW*	*14*
26	AM	67	SW	32	21	AM	*72*	*SW*	*16*
28	AM, PM	*71*	*NW*	*18*	22	AM, PM	*80*	*SW*	*23*
29	AM, PM	*75*	*S*	*26*	23	AM, PM	*88*	*SW*	*19*
May 5	AM	69	SW	19	24	AM, PM	*84*	*SW*	*24*
7	AM, PM	*73*	*S*	*20*	25	AM, PM	*76*	*SW*	*24*
8	AM, PM	*72*	*SW*	*26*	26	AM, PM	*80*	*SW*	*26*
9	AM	65	W	38	27	AM	*71*	*S*	*20*
13	AM	67	N	19	30	AM	69	W	33
14	AM	65	W	14	31	AM	65	SW	17

NOTE.—During the years 1902, 1903, and 1904 the Boston Weather Bureau did not record temperatures hourly, but took readings at 8 am and 8 pm each day. AM in the table refers to the reading made for the period from 8 am to 8 pm, while PM covers the following 12 hours. The direction of the wind and its maximum velocity did not necessarily occur when the temperature was at the maximum, for the temperature may have been 65° or even less at that time.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
1903.		°F.		*Miles per hour.*
Apr. 28	AM	66	S	13
29	AM, PM	*83*	*NW*	*19*
30	AM	*83*	*SW*	*28*
May 10	AM	*75*	*S*	*19*
11	AM	69	S	13
12	AM	*70*	*S*	*13*
13	AM	*74*	*S*	*20*
14	AM	*70*	*E*	*18*
15	AM	67	SE	10

TABLE IV.—*Temperature and direction and velocity of wind, etc.*—Continued.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
		°F.		*Miles per hour.*
1903.				
May 17	AM, PM	84	SW	19
18	AM, PM	87	NW	15
19	AM, PM	88	SW	16
20	PM, AM	80	W	16
21	AM, PM	84	S., SW	18
22	AM, PM	84	NW	21
23	AM	67	NW	27
26	AM	68	S	22
27	AM, PM	73	SW	23
28	AM, PM	75	SW	27
29	AM, PM	79	N	18
30	AM	67	N	18
1904.				
Apr. 10	AM	65	SW	19
25	AM	68	NW	14
30	AM	70	SW	14
May 3	AM	65	SW	15
4	AM, PM	80	S	20
5	AM, PM	82	W	23
7	AM, PM	81	SW	22
8	AM, PM	78	SW	25
10	AM	72	E	18
11	AM	66	E	15
12	AM	65	SE	10
17	AM	68	SW	19
20	AM	69	W	18
21	AM, PM	77	S., SW	17
22	AM, PM	81	S	24
23	AM, PM	78	S	27
24	AM, PM	84	W	16
25	PM, AM	74	SW	24
26	AM, PM	87	SW	21
27	AM	82	NW	25
28	AM, PM	75	W	23
29	AM, PM	80	SW	24
30	AM, PM	73	SW	22
31	AM	65	SE	13
1905.				
Apr. 10	11 a. m. to 6 p. m	66 to 70	SW	14 to 28
20	10 a. m. to 4 p. m	65 to 70	SW	14 to 25
21	11 a. m. to 5 p. m	66 to 72	SW	11 to 18
26	10 a. m. to 7 p. m	68 to 74	SW	12 to 25
30	1 to 5 p. m	66 to 73	W., NW	11 to 13
May 3	4 to 7 p. m	72 to 76	SW	16 to 26
6	8 a. m. to 11 p. m	65 to 79	SW	11 to 26
7	7 a. m. to 8 p. m	66 to 83	W., NW	12 to 27
8	3 to 5 p. m	65 to 67	SE., SW	13 to 18
9	11 a. m. to 2 p. m	65 to 66	NW	20 to 27
10	1 to 5 p. m	66 to 68	NW	12 to 18
11	10 a. m. to 2 p. m., 4 to 8 p. m	65 to 77	SW	10 to 19
19	10 a. m. to 6 p. m	65 to 68	W	14 to 18
22	11 a. m. to 4 p. m	66 to 71	W	11 to 14
24	4 to 6 p. m	65 to 66	SE	13 to 14
25	9 a. m. to 6 p. m	67 to 74	SW	15 to 19
26	7 a. m. to 10 p. m	65 to 78	SW	14 to 35
27	2 to 7 p. m., 9 to 10 p. m	67 to 75	SW	10 to 13
28	10 a. m. to 5 p. m	78 to 82	NW	10 to 12
29	8 a. m. to 9 p. m	70 to 83	W., SW	10 to 14
30	4 to 5 p. m	70	NW	10
1906.				
Apr. 27	1 to 6 p. m	66 to 69	W	10 to 17.
29	4 to 6 p. m	65 to 66	SW	12 to 14.
30	11 a. m. to 12 m	66	SW	18.
May 1	12 m. to 6 p. m	66 to 68	NW	15 to 18.
2	1 to 3 p. m	65 to 67	SW	10 to 17.
3	7 a. m. to 2 p. m	66 to 70	NW	16 to 28.
4	1 to 2 p. m	65	SW	12.
5	8 a. m. to 12 m	68 to 71	SW	10 to 17.
9	11 a. m. to 3 p. m	65 to 67	SE., S	22 to 37.
12	12 m. to 4 p. m., 11 p. m. to 12 p. m	65 to 69	SW	11 to 25.
13	4 a. m. to 8 p. m	65 to 83	SW., NW	12 to 27.
15	3 to 4 p. m	65	SE	10.
18	2 to 3 p. m., 10 to 11 p. m	75 to 78	SE., SW	10.
19	12 p. m. to 4 a. m., 7 a. m to 11 p. m	65 to 86	SW., NW	10 to 18.
22	1 to 5 p. m	68 to 70	SW	13 to 16.

TABLE IV.—*Temperature and direction and velocity of wind, etc.*—Continued.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
		°F.		*Miles per hour.*
1906.				
May 26	12 m. to 12 p. m.	*66* to *81*	*SW.*	*12* to *27.*
27	12 p. m. to 2 a. m., 7 a. m. to 3 p. m.	*65* to *75*	*SW.*	*10* to *15.*
30	12 m. to 6 p. m.	65 to 68	NW.	11 to 15.
31	10 a. m. to 8 p. m.	*65* to *75*	*SW.*	*10* to *13.*
1907.				
Apr. 25	11 a. m. to 5 p. m.	*65* to *70*	*SW.*	*14* to *30.*
29	4 to 6 p. m.	65 to 68	SW.	16.
30	9 a. m. to 6 p. m.	*65* to *73*	*SW.*	*13* to *25.*
May 10	9 a. m. to 6 p. m.	*66* to *72*	*SW.*	*12* to *32.*
13	10 a. m. to 6 p. m.	*65* to *75*	*SW.*	*20* to *30.*
16	8 a. m. to 5 p. m.	*65* to *74*	*SW.*	*10* to *19.*
18	7 to 11 p. m.	*65* to *70*	*SW.*	*10* to *14.*
19	2 to 7 p. m.	*69* to *81*	*SW.*	*10* to *17.*
20	11 a. m. to 2 p. m.	65 to 67	SW., NW.	10 to 19.
1908.				
Apr. 23	9 a. m. to 8 p. m.	*70* to *85*	*SW.*	*11* to *20.*
26	7 a. m. to 12 p. m.	*66* to *84*	*SW.*	*10* to *18.*
May 11	10 a. m. to 11 p. m.	*66* to *81*	*SW.*	*10* to *17.*
12	12 p. m. to 1 a. m., 7 a. m. to 12 p. m.	*69* to *84*	*SW.*	*10* to *30.*
13	12 p. m. to 12 m.	*70* to *75*	*SW., NW.*	*11* to *18.*
16	4 to 6 p. m.	65 to 68	SE., S.	15 to 16.
17	8 a. m. to 4 p. m.	*65* to *75*	*SW.*	*12* to *16.*
19	12 m. to 8 p. m.	*65* to *75*	*S.*	*10* to *17.*
23	4 p. m. to 12 p. m.	*66* to *77*	*SE., SW.*	*10* to *14.*
24	12 p. m. to 10 a. m., 12 m. to 1 p. m., 11 p. m. to 12 p. m.	*65* to *78*	*SW., NW.*	*10* to *13.*
26	7 a. m. to 12 p. m.	*66* to *87*	*SW.*	*10* to *27.*
27	12 p. m. to 7 p. m., 9 to 10 p. m.	*69* to *88*	*SW., W.*	*10* to *18.*
29	11 a. m. to 12 p. m.	*65* to *80*	*SW.*	*10* to *13.*
30	1 to 3 a. m., 1 to 2 p. m.	65 to 66	SW.	11 to 12.
31	2 a. m. to 11 p. m.	*65* to *86*	*SW.*	*10* to *19.*
1909.				
Apr. 22	2 to 6 p. m.	66 to 68	SW.	11 to 13.
May 6	8 a. m. to 4 p. m.	*68* to *83*	*SW., NW.*	*11* to *17.*
10	8 a. m. to 7 p. m., 8 to 10 p. m.	*65* to *76*	*SW.*	*11* to *27.*
11	10 a. m. to 4 p. m.	*66* to *72*	*NW.*	*10* to *22.*
12	10 a. m. to 8 p. m.	*65* to *73*	*NW.*	*11* to *21.*
13	8 to 9 a. m., 11 a. m. to 9 p. m.	*65* to *77*	*SW.*	*10* to *19.*
14	12 m. to 7 p. m.	*76* to *81*	*SW., NW.*	*11* to *14.*
15	7 a. m. to 1 p. m.	*65* to *74*	*NW.*	*10* to *15.*
24	3 to 8 p. m.	*65* to *74*	*NW.*	*12* to *13.*
26	11 a. m. to 8 p. m.	*66* to *76*	*SW.*	*10* to *17.*
27	12 m. to 4 p. m.	65 to 69	SE.	15 to 17.
30	8 to 9 a. m., 12 m. to 7 p. m.	*65* to *70*	*NW.*	*14* to *25.*
31	7 a. m. to 11 p. m.	*66* to *80*	*NW.*	*11* to *20.*
1910.				
Apr. 6	10 a. m. to 7 p. m.	*65* to *78*	*SW.*	*10* to *13.*
7	11 a. m. to 2 p. m.	65 to 67	SW., NW., W.	10 to 13.
14	12 m. to 7 p. m.	65 to 69	W., NW.	10 to 17.
15	11 a. m. to 5 p. m.	*66* to *73*	*NW.*	*11* to *15.*
19	5 to 6 p. m.	66 to 67	SE.	12.
20	2 to 4 p. m.	66 to 68	SW.	17 to 18.
27	12 m. to 6 p. m.	66 to 69	SW., NW.	11 to 14.
30	3 to 6 p. m.	66	SW.	10 to 12.
May 7	11 a. m. to 8 p. m.	*65* to *70*	*NW., W.*	*10* to *17.*
8	11 a. m. to 3 p. m.	*66* to *76*	*SW.*	*10* to *18.*
10	12 m. to 6 p. m.	65 to 68	NW.	15 to 27.
11	12 m. to 3 p. m.	65 to 66	W.	13 to 19.
17	2 to 8 p. m.	*66* to *71*	*SE.*	*10* to *12.*
18	10 to 11 a. m.	65	SW.	18.
19	1 to 6 p. m.	65 to 68	NW.	17 to 26.
20	3 to 7 p. m.	*68* to *76*	*SW.*	*10* to *14.*
23	12 m. to 7 p. m.	*65* to *75*	*SW.*	*11* to *15.*
24	4 to 5 a. m., 7 to 10 a. m., 12 m. to 11 p. m.	*65* to *86*	*SW.*	*10* to *17.*
25	12 p. m. to 3 a. m., 6 a. m. to 8 p. m.	*65* to *74*	*SW.*	*12* to *17.*
26	11 a. m. to 7 p. m.	*68* to *76*	*SW., NW.*	*11* to *14.*
27	12 m. to 1 p. m.	65	W.	11.
28	12 m. to 1 p. m.	66	NW.	12.
29	12 m. to 1 p. m.	65	SE.	10.
1911.				
Apr. 26	3 to 5 p. m.	65 to 68	SE., SW.	10 to 17.
27	8 to 10 a. m., 12 m. to 9 p. m.	*65* to *80*	*SW.*	*10* to *15.*
28	12 m. to 1 p. m., 7 to 8 p. m.	*74* to *79*	*SE., SW.*	*10* to *11.*
29	12 p. m. to 1 a. m., 5 to 7 p. m.	*65* to *76*	*SW.*	*10* to *11.*
30	8 a. m. to 4 p. m.	*65* to *75*	*SW.*	*11* to *28.*

TABLE IV.—*Temperature and direction and velocity of wind, etc.*—Continued.

Date.	24 hours.	Temperature.	Direction of wind.	Velocity of wind.
1911.		°F.		*Miles per hour.*
May 1	12 m. to 6 p. m.	*66* to *72*	*SW.*	*11* to *13.*
2	8 a. m. to 12 m.	65 to 68	W.	14 to 18.
5	2 to 3 p. m.	65	SW.	10.
6	12 m. to 6 p. m.	65 to 68	SE.	11 to 17.
7	9 a. m. to 4 p. m.	*72* to *81*	*W., NW.*	*10* to *14.*
8	12 m. to 8 p. m.	*66* to *81*	*SW.*	*10* to *17.*
9	1 to 2 p. m.	*70*	*SW.*	*12.*
10	7 a. m. to 4 p. m.	*67* to *72*	*NW.*	*11* to *25.*
11	9 a. m. to 12 p. m.	*69* to *84*	*SW.*	*11* to *25.*
12	12 p. m. to 8 p. m.	*67* to *81*	*SW.*	*10* to *19.*
13	9 a. m. to 7 p. m.	*66* to *80*	*W., NW.*	*13* to *18.*
15	10 a. m. to 6 p. m.	*65* to *73*	*SW.*	*10* to *19.*
16	9 a. m. to 1 p. m.	*69* to *75*	*NW.*	*10* to *15.*
17	5 to 7 p. m.	*66* to *71*	*SE., SW.*	*10* to *14.*
18	8 to 11 a. m., 4 to 5 p. m.	*69* to *82*	*W.*	*10.*
21	12 m. to 12 p. m.	*70* to *87*	*SW.*	*11* to *14.*
22	12 p. m. to 3 a. m., 5 to 7 a. m., 10 p. m. to 12 p. m.	*69* to *79*	*SW.*	*10* to *11.*
23	12 p. m. to 1 a. m.	*76*	*NE.*	*10.*
28	11 a. m. to 12 p. m.	*65* to *86*	*SW.*	*10* to *14.*
29	5 a. m. to 12 p. m.	*67* to *88*	*SW.*	*10* to *19.*
30	4 to 5 a. m.	68	N.	10.

During the entire period covered by these records 51 per cent of the days when spread was possible the wind was southwest. Figure 3 shows graphically the proportion of the time when the wind blew in each direction, as given in the above tables.

In the fall of 1907 the gipsy moth was found extensively in New Hampshire, especially in the eastern part, and as a small strip along the seacoast in Maine was also infested. Weather Bureau records are here added, which have been secured from the Concord, N. H., and Portland, Me., stations.

FIG. 3.—Diagram showing the proportion of time the wind blew in each direction, when wind spread was possible, during April and May for 10 years, 1902–1911. Records from Boston office of Weather Bureau. (Original.)

TABLE V.—*Temperature, direction, and velocity of wind on dates after hatching of caterpillars, 1907–1911.*

CONCORD, N. H.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
1907.		°F.		*Miles per hour.*
Apr. 23	12 to 4	65	SW., SE.	10 to 13
29	2 to 5	66	S.	10 to 11
30	8 to 7	*74*	*SW., S.*	*12* to *20*
May 10	9 to 7	66	NW.	10 to 16
13	7 to 9	79	*SW.*	*11* to *16*
14	12 to 5	*81*	*SE.*	*10* to *14*
1908.				
Apr. 23	12 to 3, 5 to 6	*79*	*NW.*	*10* to *14*
25	11 to 7	68	SE.	10 to 13
26	9 to 5	*80*	*SW., W.*	*10* to *19*
27	10 to 5	*73*	*SE.*	*11* to *14*

TABLE V.—*Temperature, direction, and velocity of wind, etc.*—Continued.

CONCORD, N. H.—continued.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
		°F.		Miles per hour.
1908.				
May 11	11 to 4	79	NW	10 to 14
12	9 to 6	83	SW	10 to 15
13	9 to 6	68	SW	10 to 15
16	3 to 6	74	SE	10 to 14
17	12 to 3	73	SW., W	10 to 12
18	5 to 6	79	SE	11
19	10 to 7	76	SE., S	10 to 13
21	1 to 7	75	SE	10 to 13
24	10 to 5	81	NW	10 to 11
26	11 to 7	89	SW	10 to 15
27	8 to 1	85	W	10 to 12
30	12 to 3	75	E., SE	10 to 11
31	8 to 5	82	SW	10 to 14
1909.				
May 6	8 to 4	74	NW	10 to 13
8	4 to 6	69	SE	11 to 13
10	11 to 7	78	S	15 to 19
11	9 to 7	68	NW	10 to 25
12	8 to 6	68	NW	11 to 25
14	11 to 5	78	W	10 to 13
15	7 to 10, 2 to 5	71	NW	10 to 11
24	8 to 9, 11 to 6	74	NW	10 to 13
26	4 to 5	74	W	10
27	12 to 1	73	SE	10
30	7 to 6	68	NW	11 to 19
31	9 to 6	76	NW	11 to 18
1910.				
Apr. 6	12 to 6	70 to 80	SE., S	11 to 16
15	2 to 3	66	NW	13
19	12 to 5	68 to 72	SE., E	10 to 13
27	2 to 4	66 to 67	W	10
May 3	3 to 4	69	SE	10
7	1 to 4	65 to 67	W	10 to 11
8	2 to 5	65 to 73	SW	10 to 13
23	2 to 6	65 to 69	SE	10
24	10 to 5	82 to 86	SW	10 to 11
25	8 to 4, 6 to 7	66 to 77	SW., S	10 to 16
26	1 to 4	66 to 69	W	10 to 12
27	1 to 2	66	W	10
28	10 to 4	65 to 71	NW., N	11 to 15
29	3 to 4	73	SE	11
1911.				
Apr. 30	10 to 6	68 to 80	S, SW	11 to 16
May 1	10 to 5	67 to 71	SW, S	11 to 13
7	9 to 5	71 to 79	NW	10 to 12
8	5 to 6	77	S	13
10	8 to 1, 2 to 4	65 to 76	NW	10 to 14
11	1 to 8	79 to 89	SW	10 to 15
12	9 to 5	82 to 85	SW	10 to 14
13	9 to 5	65 to 71	NW	11 to 15
14	5 to 6	65	SE	12
15	10 to 6	70 to 73	SW	12 to 15
16	9 to 12, 1 to 3, 4 to 5	66 to 74	N	10 to 12
26	4 to 5	70	E	11
29	11 to 3, 5 to 6	76 to 91	W, SW, NW	10 to 12
31	1 to 4	66 to 73	SE	10 to 12

TABLE V.—*Temperature, direction, and velocity of wind, etc.*—Continued.

PORTLAND, ME.

Date.	Hours 7 a. m. to 7 p. m.	Maximum temperature.	Direction of wind.	Velocity of wind.
		° *F.*		*Miles per hour.*
1907.				
May 10	10 to 2	65 to 67	W	12 to 32
19	10 to 2	67 to 70	SE	10 to 14
20	1 to 3	65	W	18 to 20
1908.				
Apr. 23	10 to 5	67 to 75	W	13 to 20
26	10 to 7	73 to 81	SW., W	10 to 21
May 11	11 to 1, 3 to 5	66 to 77	N., NW	12 to 23
12	12 to 2, 4 to 5	67 to 69	S	13 to 14
13	10 to 11	65	N	12
18	3 to 4	67	S	10
19	11 to 3	66 to 71	S	11 to 18
26	11 to 7	67 to 75	S	12 to 18
27	8 to 5	78 to 87	W., NW	10 to 15
31	7 to 5	69 to 84	W., SW	13 to 20
1909.				
May 6	9 to 5	65 to 75	NW	14 to 19
11	1 to 2	66	S	11
12	11 to 5	65 to 67	NW	21 to 36
13	12 to 3	67 to 70	W	11 to 13
15	1 to 6	66 to 68	NW	12 to 14
26	9 to 4	66 to 70	NW., S	10 to 17
27	12 to 1	68	SE	10
30	2 to 6	65 to 67	NW	20 to 24
31	8 to 7	65 to 74	NW	12 to 24
1910.				
Apr. 14	1 to 3	65	W	20 to 21
27	12 to 3	67 to 68	SW	10 to 15
May 10	2 to 3	65	W	19
17	11 to 5	65 to 69	SE., S	11 to 15
20	9 to 1	65 to 67	NW., S	11 to 15
24	11 to 5	65 to 68	S	10 to 16
25	12 to 2	65 to 67	S	14 to 18
26	12 to 2	65 to 66	S	11 to 15
27	12 to 4	65 to 68	SE	10 to 15
1911.				
Apr. 27	2 to 3	65	SE	10
28	9 to 10, 2 to 9	65 to 73	S., SW	10 to 14
29	1 to 6	65 to 77	S	10 to 12
May 2	8 to 1	66	W	18 to 20
7	8 to 9, 10 to 6	68 to 80	W., NW	10 to 18
8	10 to 5	65 to 75	S	13 to 19
10	8 to 11, 1 to 3, 4 to 6	65 to 75	NW., N., S	10 to 15
12	6 to 7, 10 to 2	66 to 78	S., SW	11 to 18
13	8 to 5	66 to 76	W., NW	14 to 20
16	10 to 6	65 to 73	NW., W	12 to 16
17	12 to 1	67	S	11
18	1 to 3	67 to 74	SE	11
21	9 to 9	65 to 73	S	11 to 18
22	2 to 5	84 to 88	S	10
27	11 to 3	65 to 69	S	12 to 16
28	10 to 9	66 to 76	S	11 to 20
29	9 to 6	74 to 80	S	10 to 12
30	1 to 4	66 to 70	S	10 to 13

In order to study these tables properly the data from each State should be considered separately. Hatching takes place later in the vicinity of Portland, Me., and Concord, N. H., than in the territory surrounding Boston, because the season is later. In Massachusetts the same conditions prevail in all of the towns which are on the watersheds of the Merrimac and Connecticut Rivers. An examination of the records, however, shows that the prevailing winds

are in the same direction during the first half of June as in the month of May, so that little benefit would be derived from giving the additional data.

For convenience the record of infestation has been divided into four periods (see map 1), viz:

(1) The territory infested in 1900 at the time the work was discontinued by the State of Massachusetts.

(2) The territory found infested as a result of scouting operations after the work was resumed in the winter of 1905–6 by the State of Massachusetts.

(3) The territory found infested up to and including the winter of 1908–9.

(4) The territory infested at the present time, winter of 1911–12.

The territory infested in 1900 when the gipsy-moth work was discontinued by the State of Massachusetts was confined to 34 towns and cities surrounding Boston, covering an area of about 359 square miles. None of the area was badly infested, but a very rapid increase of the pest took place as soon as efforts to check it were abandoned. The next two years developed few signs of increase in the insect, although in several localities it was somewhat abundant in 1902. An infestation was discovered in Providence, R. I., in the summer of 1901. In the summers of 1903, 1904, and 1905 the territory in Massachusetts which had been most densely infested when the work was discontinued fairly swarmed with caterpillars, and, as little organized effort was made to check the insect, an excellent opportunity was offered for the small caterpillars to be spread by the wind. Map 1 shows the territory which was found infested by the scouting operations conducted by the State of Massachusetts, which were carried on during the summer and fall of 1905. The infestation had increased to such an extent that it covered 132 towns and extended from Portsmouth, N. H., to Buzzards Bay, including, as well, isolated colonies in Providence and Cranston, R. I., and Stonington, Conn., a total of about 2,224 square miles.

Undoubtedly the greater part of this infestation was the result of wind spread, therefore map 1 indicates the number of days the wind blew in each direction during the period when caterpillars were in the first stage, and when the temperature and wind velocity were favorable to their dispersion. Eliminating the west wind from consideration, which would take the larvæ out to sea, it will be noted that, except for seven days when it was from the east and north, the direction of the wind would account in a general way for the infested region as shown by the map. It is probable that more area would have been found infested in southern New Hampshire in 1905 if it had been possible to scout the towns nearest Massachusetts, but there were no funds available for this purpose.

During the period from 1906 to 1909 a large extent of scouting was done by the State of Massachusetts in the territory outside of the area known to be infested, and, as a result, 44 new towns and cities were found infested. Isolated colonies were found at Greenfield, at Palmer, at Springfield, and at Warren during the scouting operations, but all of them have since been exterminated. In New Hampshire scouting work was carried on under the direction of Mr. D. M. Rogers, special agent of the Bureau of Entomology. The infested area was found to have greatly increased. Scouting was also carried on in Maine and Rhode Island and showed that the infested area was increasing, and one isolated colony was found in Togus, Me. At the close of this period of scouting the entire area of infestation covered nearly 7,300 square miles. The greater part of the spread had been toward the northeast and northwest, and it is interesting to note that the prevailing winds blew in these directions, especially from the southwest. (See map 1.)

During the period from 1909 to 1912 the infested territory has continued to increase. Nearly all the scouting work has been done by agents of the Bureau of Entomology, although a small force has been employed by the States of Maine, Massachusetts, and Connecticut. The infested territory has continued to increase along the line of the prevailing winds, as is shown on map 1 and by its wind diagram. In the fall of 1909 an isolated colony was found at Wallingford, Conn., but careful scouting for miles in all directions has failed to locate other infestations in that part of the State. It is probable that egg clusters were brought to Wallingford on market boxes or in packing material. The thorough treatment which has been given under the direction of the State entomologist, Dr. W. E. Britton, and his assistant has reduced the colony to a point approaching extermination. The same is true of the colony at Stonington, Conn.

In the summer of 1911 the gipsy moth was discovered on an estate in the town of Lenox in the western part of Massachusetts, and scouting work has resulted in locating it in Stockbridge and Great Barrington. It is probable that in Lenox and Stockbridge the infestation resulted from the receipt of a carload of nursery stock (Pls. XIV, XV, XVI) which was shipped by the Boston Park Department about 1909 to the estate where the infestation was found. The origin of the Great Barrington infestation is obscure, but further scouting of the town may uncover conditions which will explain the reason. The colony at Togus, Me., has been exterminated, no specimens having been found since 1908.

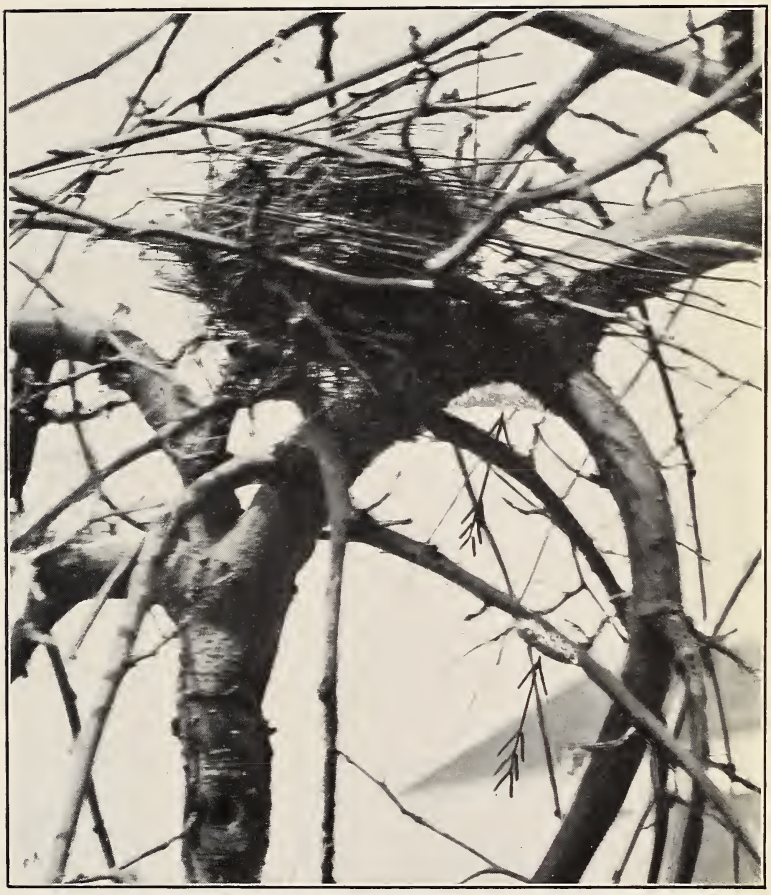
As a result of the scouting operations during the past winter it is shown that 10,900 square miles are now infested with the gipsy moth. The territory which is now badly infested is well outside

ROW OF LARGE MAPLE NURSERY STOCK INFESTED BY THE GIPSY MOTH.

A gipsy-moth egg cluster is on the tree in the center of the picture, as indicated by arrow, just above the black spot. (Original.)

GIPSY-MOTH EGG CLUSTER ON SMALL NORWAY SPRUCE TREE IN NURSERY ROW.

The upper branches of the tree have been tied up so as to expose the egg cluster. (Original.)



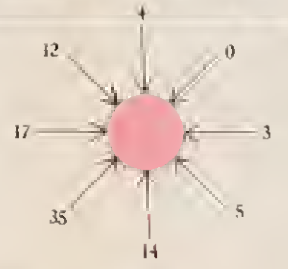
WEEPING MULBERRY SHOWING BIRD'S NEST AND NEAR BY TWO GIPSY-MOTH EGG CLUSTERS.

Their location is indicated by the arrows. The egg cluster in the background is nearly obscured by the shadow. (Original.)

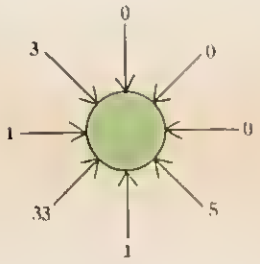
Bul 119, Bureau of Entomology, U. S. Dept. of Agriculture.

MAP No. 1.

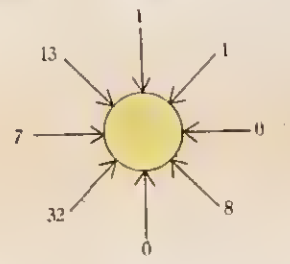
Boston, Mass., 1902-1905.



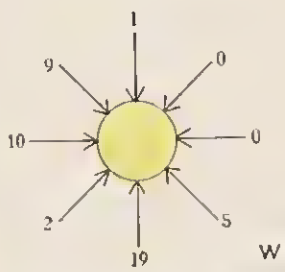
Boston, Mass., 1906-1908.



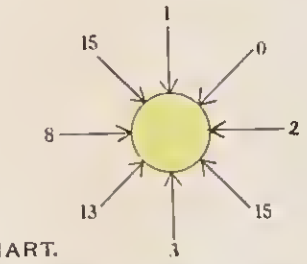
Boston, Mass., 1909-1911.



Portland, Me., 1909-1911.



Concord, N. H., 1909-1911.



WIND CHART.

Wind chart indicating total number of days in which the wind blew in the directions of the arrows, for April and May of the years mentioned and when the temperature was above 65°. These were the days favorable for wind spread. Colored circles show area to which larvæ were dispersed during the period.

MAP
showing
DISPERSION AND PRESENT DISTRIBUTION
of the
GIPSY MOTH IN NEW ENGLAND.

TOWNS AND CITIES WHOLLY OR IN PART INFESTED IN 1900 WHEN WORK UNDER BOARD OF AGRICULTURE WAS DISCONTINUED

TOWNS AND CITIES FOUND TO BE INFESTED AFTER ACTIVE WORK WAS RESUMED IN 1905.

TOWNS AND CITIES FIRST FOUND INFESTED 1906-1909.

TOWNS AND CITIES FIRST FOUND INFESTED 1909-1912.

SCALE OF MILES

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of that which was infested in 1905. This being the case, the opportunity for spread has greatly increased, and as the insect gradually becomes established on the western slope of the high lands in the central part of the State, the opportunity for serious damage in the Connecticut valley is rapidly increasing.

In connection with the weather record given for this period it is interesting to note the corresponding data from the Weather Bureau stations at Portland, Me., and at Concord, N. H., as these data have a bearing upon the spread in the northern part of the territory.

GENERAL SUMMARY.

The map and wind direction records give a fairly good idea of the dispersion of the gipsy moth. The spread has been along the lines of the prevailing winds to so great an extent that the evidence is conclusive that natural spread is accomplished chiefly in this way. All the records bear out this conclusion. It should be noted in the Concord records that the southeast winds were the ones which were most likely to carry the larvæ into new territory, while in Portland the south and west winds which predominated would do the same thing in that section. It should be remembered that neither Concord, N. H., nor Portland, Me., has been badly infested and that the spread must come from bad colonies nearer the center of infestation.

The general "seeding down" of slightly infested territory by larvæ spread by the wind is shown in some detail in the following pages.

GENERAL CONCLUSIONS.

It is impossible to give a detailed explanation of the cause of every infestation. The weather records give strong evidence that the wind is responsible in a large degree for the spread of the gipsy moth, but the spread can be brought about only under the favorable conditions which have already been explained. The present apparatus for recording wind movements is somewhat imperfect, and as the wind is usually very variable it is probable that a greater local spread results than can be explained from wind records. Other things being equal, wind spread will start the most vigorous colonies nearest the bad centers of infestation,[1] for the farther the caterpillars are carried the more chance there is for them to become widely separated, so

[1] On May 19, 1912, Mr. C. W. Stockwell found that large numbers of first-stage gipsy-moth larvæ that hatched a few days before were being blown from an isolated block of birches into a pasture by a strong southwest wind. At a point 125 feet from this block he found from 21 to 27 larvæ per square foot; they were crawling about on the grass seeking food. On the posts of a wire fence, 185 feet from the birches, over 500 larvæ were found on each post, and smaller numbers of larvæ were found at a greater distance away. This substantiates the experiments previously made, and shows what happens in nature under favorable conditions. It also proves that the heaviest infestations brought about by wind spread will be nearest the colony from which the larvæ were spread.

that infertile egg clusters will result in case any are deposited. Cases are on record where a male gipsy moth has been attracted half a mile by a female. This factor probably assists the species in becoming established at distant points.

RELATION OF SCOUTING RECORDS TO WIND DISPERSION.

The records which have accumulated showing the number of egg clusters found and treated by scouts in the various towns, as well as the reports of the work done by local superintendents, have been examined for the purpose of determining whether information could be secured that would have any bearing on the dispersion of the insect. As a result of the examinations it appears impossible to give data covering the entire territory, since the records are incomplete in many cases and they have been kept in various ways so as to make a comparison of little value. The plan has been to select several towns and cities (see fig. 4) where complete records were obtained. The geographical locations of these are typical, so that the results will serve to illustrate the relation of wind to infestation as found by scouts. It should be remembered that no woodland area is included in the records cited, for only roadsides, orchards, and the grounds about residences were examined.

In order to check this data a complete scout has been made of several towns by employees of the Bureau of Entomology, United States Department of Agriculture, working under the direction of Mr. Rogers. This included a careful examination of the wooded areas as well as the roadside trees.

RECORDS OF DISPERSION OF THE GIPSY MOTH SECURED FROM REPORTS OF SCOUTING IN SEVERAL SELECTED CITIES.

For the purpose of making a comparison showing the rapidity of infestation in different localities (fig. 4) the cities of Brockton and Worcester, Mass., and Nashua, Manchester, Concord, and Portsmouth, N. H., are given in Table VI.

TABLE VI.—*Record of egg clusters of the gipsy moth found in certain cities of New England during the years 1905–11.*

Cities.	1905–6	1906–7	1907–8	1908–9	1909–10	1910–11
Massachusetts:						
Brockton	24	127	283	3,101	1,575	5,600
Worcester	0	0	44	32	31	275
New Hampshire:						
Nashua	0	9	176	910	16,759	[1] 17,607
Manchester	0	2	53	456	([2])	[1] 16,598
Concord	0	0	([3])	93	1,855	4,419
Portsmouth	2	175	802	9,417	72,294	[1] 72,000

[1] Estimated. [2] No record. [3] 1 pupa.

The records for the winter of 1911–12 are not given, as it was impossible to secure the information from some of the cities mentioned. The data concerning the infestation in cities and towns in Massachusetts have been kindly furnished by State Forester F. W. Rane and his assistants, while similar data from the other States have been supplied by Mr. Rogers. It will be noted that the city of Brockton was found infested in 1905–6 and that the same is true of Portsmouth, N. H. An excellent opportunity is offered for comparing the number of egg clusters found in these two cities from year to year. It will be observed that at the end of the fifth year 1,575 egg clusters were found in Brockton, while over 72,000 were treated in Portsmouth, N. H. This indicates very strongly that new infestations were continually being brought about through the spread of caterpillars by the wind.

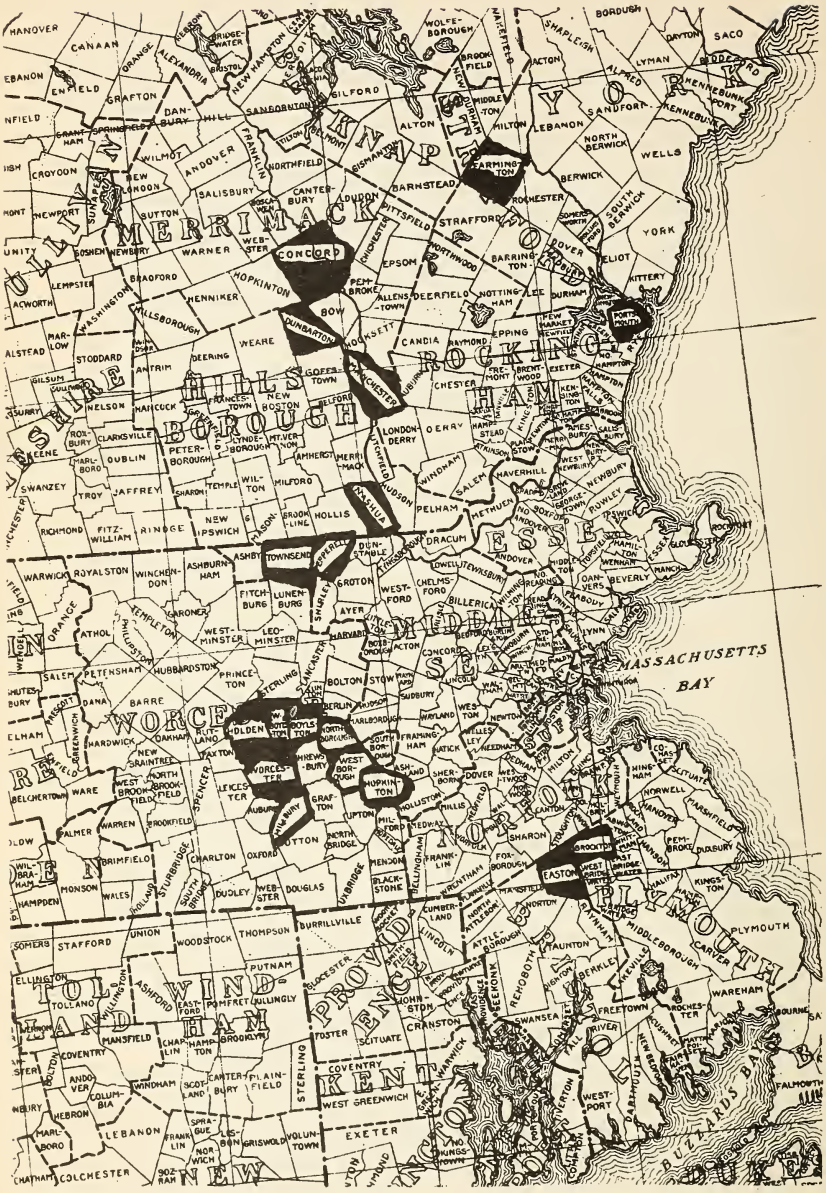
Somewhat the same conditions will be noted on comparing the record of infestation at Worcester with that of Nashua, Manchester, and Concord. The increase in Worcester for the period shown in the table is slightly less than that in Brockton, which shows that the wind was more favorable for spread in the direction of the latter city.

It should be noted that all the newly infested points were treated each year, and in many cases colonies were exterminated, but as a rule a larger number of new infestations were found in different parts of the cities the next year, and the total of egg clusters usually showed an increase.

In connection with these data it is interesting to consider the record of infestation in the State of Rhode Island. The gipsy moth was first found in the city of Providence in 1901, and some work was done to control the insect during the five succeeding years.

In 1906–7 a careful examination was made by agents of the Bureau of Entomology in cooperation with the State of Rhode Island, and several towns surrounding that city were found infested. In all, 79,000 egg clusters were found and treated. In 1907–8, 7,500 egg clusters were found, and the following winter only 1,164 were discovered. During the next two winters there was a slight increase in the number of egg clusters found, as several newly infested places were discovered. No work was done in the summer of 1911, because the State failed to provide the necessary funds. During the winter of 1911–12 an examination made by the agents of the Bureau of Entomology showed that the insect had increased rapidly, 37,293 egg clusters having been found and five new towns having been infested.

The territory infested includes both city and country, and the figures show how rapidly reinfestation takes place after suppression work is stopped. The data also indicate that the rate of increase is


MERRIMACK
CONCORD
ROCKINGHAM
HILLSBOROUGH
STRAFFORD
BELKNAP
CARROLL
GRAFTON
COOS
SULLIVAN
CHESHIRE
KEENE
NASHUA
MANCHESTER
PORTSMOUTH
DOVER
ROCHESTER
FARMINGTON
LACONIA
BERLIN
LITTLETON
NEWPORT
CLAREMONT
HANOVER
LEBANON
HAVERHILL
LAWRENCE
LOWELL
ANDOVER
SALEM
BEVERLY
GLOUCESTER
ESSEX
MIDDLESEX
MASSACHUSETTS BAY
WORCESTER
FITCHBURG
LEOMINSTER
GARDNER
ATHOL
GREENFIELD
NORTHAMPTON
SPRINGFIELD
HOLYOKE
CHICOPEE
WESTFIELD
PITTSFIELD
NORTH ADAMS
HOOSAC TUNNEL
HAMPSHIRE
FRANKLIN
HAMPDEN
BERKSHIRE
NEW BEDFORD
FALL RIVER
TAUNTON
PLYMOUTH
BARNSTABLE
PROVINCETOWN
NANTUCKET
DUKES
BUZZARDS BAY
CAPE COD
WORCESTER
WEBSTER
DUDLEY
SOUTHBRIDGE
GRAFTON
MILFORD
UXBRIDGE
BLACKSTONE
MENDON
NORTHBRIDGE
SUTTON
MILLBURY
SHREWSBURY
WESTBOROUGH
HOPKINTON
HOLLISTON
FRAMINGHAM
NATICK
WELLESLEY
NEEDHAM
DEDHAM
MILTON
QUINCY
BRAINTREE
HINGHAM
HULL
COHASSET
SCITUATE
MARSHFIELD
PEMBROKE
DUXBURY
KINGSTON
HALIFAX
PLYMPTON
CARVER
PLYMOUTH
MIDDLEBOROUGH
LAKEVILLE
ROCHESTER
WAREHAM
MARION
MATTAPOISETT
FAIRHAVEN
ACUSHNET
FREETOWN
SWANSEA
SOMERSET
DIGHTON
REHOBOTH
SEEKONK
BERKLEY
RAYNHAM
EASTON
BROCKTON
WEST BRIDGEWATER
BRIDGEWATER
ABINGTON
WEYMOUTH
RANDOLPH
HOLBROOK
STOUGHTON
CANTON
MILTON
DORCHESTER
BOSTON
CHELSEA
REVERE
WINTHROP
LYNN
SAUGUS
MALDEN
MEDFORD
SOMERVILLE
CAMBRIDGE
WATERTOWN
NEWTON
BROOKLINE
WELLESLEY
WESTON
WALTHAM
LEXINGTON
BEDFORD
BILLERICA
CHELMSFORD
TEWKSBURY
WILMINGTON
READING
NORTH READING
WOBURN
STONEHAM
MELROSE
WAKEFIELD
SAUGUS
LYNNFIELD
PEABODY
DANVERS
MIDDLETON
TOPSFIELD
BOXFORD
GEORGETOWN
GROVELAND
NEWBURY
NEWBURYPORT
WEST NEWBURY
MERRIMAC
AMESBURY
SALISBURY
SEABROOK
HAMPTON
NORTH HAMPTON
EXETER
NEWMARKET
DURHAM
NEWINGTON
GREENLAND
NEW CASTLE
RYE
NEW CASTLE
KITTERY
ELIOT
YORK
SOUTH BERWICK
BERWICK
NORTH BERWICK
WELLS
KENNEBUNK
KENNEBUNKPORT
BIDDEFORD
SACO
OLD ORCHARD
SANFORD
LEBANON
MILTON
ACTON
BOXBOROUGH
HUDSON
STOW
BOLTON
HARVARD
LANCASTER
SHIRLEY
AYER
GROTON
PEPPERELL
DUNSTABLE
TYNGSBOROUGH
DRACUT
ASHBY
TOWNSEND
ASHBURNHAM
WINCHENDON
ROYALSTON
ORANGE
PETERSHAM
HUBBARDSTON
BARRE
PRINCETON
WESTMINSTER
TEMPLETON
PHILLIPSTON
WARWICK
NEW IPSWICH
RINDGE
FITZWILLIAM
TROY
JAFFREY
SHARON
TEMPLE
WILTON
MILFORD
AMHERST
MERRIMACK
LONDONDERRY
DERRY
WINDHAM
SALEM
PELHAM
METHUEN
NASHUA
HOLLIS
BROOKLINE
MILFORD
HOPKINTON
HENNIKER
WARNER
WEBSTER
BOSCAWEN
NEWBURY
SUNAPEE
CLAREMONT
CANAAN
ENFIELD
GRANTHAM
NEWPORT
CROYDON
LEMPSTER
ACWORTH
CHARLESTOWN
WALPOLE
ALSTEAD
MARLOW
STODDARD
GILSUM
SULLIVAN
NELSON
MARLBOROUGH
ROXBURY
CLARKSVILLE
STODDARD
DEERING
WASHINGTON
HILLSBOROUGH
BRADFORD
NEWBURY
BOSCAWEN
CONCORD
PEMBROKE
ALLENSTOWN
PITTSFIELD
EPSOM
NORTHWOOD
BARRINGTON
NOTTINGHAM
LEE
DURHAM
NEWMARKET
EPPING
RAYMOND
CANDIA
AUBURN
DEERFIELD
NORTHFIELD
CANTERBURY
LOUDON
BARNSTEAD
GILMANTON
ALTON
GILFORD
LACONIA
MEREDITH
CENTER HARBOR
MOULTONBOROUGH
TUFTONBORO
WOLFEBOROUGH
BROOKFIELD
MIDDLETON
NEW DURHAM
FARMINGTON
ROCHESTER
SOMERSWORTH
SOUTH BERWICK
BERWICK
NORTH BERWICK
WELLS
KENNEBUNK
KENNEBUNKPORT
BIDDEFORD
SACO
OLD ORCHARD
SANFORD
LYMAN
ALFRED
SHAPLEIGH
BOWDOIN
DAYTON
BOWDOIN
BRISTOL
NEW HAMPTON
DANBURY
SANBORNTON
FRANKLIN
NORTHFIELD
TILTON
BELMONT
SANBORNTON
GILFORD
ALTON
BARNSTEAD
GILMANTON
CANTERBURY
LOUDON
CHICHESTER
PITTSFIELD
STRAFFORD
NORTHWOOD
NOTTINGHAM
DEERFIELD
ALLENSTOWN
PEMBROKE
HOPKINTON
HENNIKER
WARNER
WEBSTER
BOSCAWEN
CONCORD
BOW
DUNBARTON
HOOKSETT
CANDIA
RAYMOND
EPPING
NEWFIELDS
NEWINGTON
DOVER
ROLLINSFORD
SOMERSWORTH
ROCHESTER
FARMINGTON
MILTON
LEBAN

much less in this State than in the cities in New Hampshire noted in Table VI, which is due largely to the fact that the region is out of the line of natural spread and reinfestation by the wind.

The common trees growing in Rhode Island are as much if not more favored for food than those in the cities mentioned.

RECORDS OF DISPERSION SECURED FROM SEVERAL SELECTED TOWNS.

In order to check the data just given the records of several outlying towns (fig. 4) in different sections of the infested district are supplied in the accompanying table.

TABLE VII.—*Record of egg clusters of the gipsy moth found in certain towns of New England during the years 1906–1912.*

Towns.	1906–7	1907–8	1908–9	1909–10	1910–11	1911–12
Massachusetts:						
Easton	3	8	47	141	503	1,789
Hopkinton	267	1,417	4,283	2,124	3,448	(1)
Westboro	(2)				846	1,897
Northboro			(3)	14	341	142
Boylston				1	140	1,421
West Boylston				7	156	378
Holden		(3)		9	45	455
Millbury		32	12	3	4	33
Pepperell	4	87	765	(1)	(1)	(1)
Townsend		1	4	524	3,613	4 12,862
New Hampshire:						
Dunbarton			25	308	2,825	42,147
Farmington			125	1,170	3,260	(1)

[1] No record. [2] 7 collected. [3] 1 pupa. [4] Partial record.

The record of infestation—that is, the record showing the number of egg clusters found while scouting various towns from year to year—is interesting, as it gives in a way the rate of increase, although it should be understood that all egg clusters which are found are treated with creosote, and in most cases the infested areas are attended to during the caterpillar season and all the larvæ found are destroyed. Only roadsides, orchards, and private estates are examined and treated. In most cases the towns have large woodland areas which it is impossible to examine owing to the expense involved. The record of the infestation is given for several towns, which shows that dispersion must be due to causes other than vehicles.

The data for the town of Easton were furnished by Mr. L. W. Hodgkins, an agent of the State forester of Massachusetts, who had charge of a section of southeastern Massachusetts for several years. The town has been examined and the infestations treated each year, the number of egg clusters showing a slow but continuous increase since 1906, the year when the first infestation was found. During

that year single egg clusters were discovered in each of three localities. In the fall of 1911, 1,789 were found in 326 localities.

The gipsy moth was first found in Hopkinton, Mass., in 1905, and the writer is indebted to Mr. G. A. Sands, of the Massachusetts State forester's office, for data concerning this town. During the winter of 1906–7, 267 egg clusters were secured from 39 different localities. In 1907–8, 1,417 egg clusters were secured in 30 localities. In 1908–9, 4,283 egg clusters were found in 90 colonies. In 1909–10, 2,124 egg clusters were treated in 70 localities. In 1910–11, 3,448 egg clusters were found in 80 localities. In some of these colonies no egg clusters were located during the year following the first examination, as the trees were burlaped, examined during the summer, and the colonies exterminated. In other places small numbers of egg clusters were found from year to year, but each year it was possible to obtain them in regions where they had not been known previously.

The original colony in Hopkinton was southeast of the village, near the roadside. The following year infested places were found near the center of the town, and a few were located near the borders of the adjoining towns. The next year egg clusters were found well scattered throughout the town, especially in the residential section, and this condition prevails at the present time. Owing to the location of the various infestations, it is highly improbable that the insects could have spread by artificial means. For the past two years very little work has been done in this town to suppress the moth.

The data for several towns following were supplied by Mr. H. B. Ramsey, an agent of the Masachusetts State forester, and the writer is indebted to him for this and other valuable information furnished.

The condition in Westboro, a town northwest of Hopkinton, was not so bad in 1906–7, there having been found at that time only seven colonies. The number of colonies, however, steadily increased. In 1910–11, 116 were located, containing 846 egg clusters, while in 1911–12, 1,897 egg clusters were found in 214 localities.

Directly northwest of Westboro is the town of Northboro, in which no egg clusters were found until the winter of 1909–10, although three pupal cases were secured during the previous year. Northboro is west of Marlboro, which was found infested in 1905, and if dispersion of the species was equal in all directions, should have become infested rapidly. During the winter of 1909–10 five colonies were found, 14 egg clusters being treated in them. They were located in the southeastern and north-central parts of the town. The following year 95 colonies were secured, and in these 341 egg clusters were treated. In 1911–12, 1,421 egg clusters were found on 180

estates. The colonies were scattered through practically every section of the town, a few more being found near the center than in the outskirts.

Northwest of the town of Northboro is the town of Boylston (fig. 5). One egg cluster was found here in the winter of 1909–10, and during the following year 140 were found in 41 different localities. In 1911–12 141 egg clusters were found in 41 localities scattered over the town.

West Boylston, a town directly west of Boylston, was scouted by the inspectors employed by the State of Massachusetts in the winters of 1907–8 and 1908–9, but no egg clusters were found. During the winter of 1909–10 seven were secured on five estates, and during the following winter 30 estates were found infested with 156 egg clusters. During the winter of 1911–12 378 egg clusters were found on 75 estates.

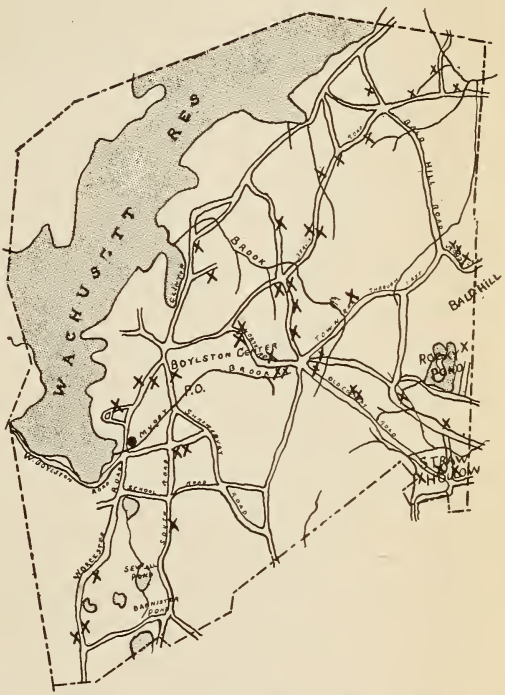


FIG. 5.—Map of town of Boylston, Mass., showing increase in gipsy-moth-infested localities, 1909–10 and 1910–11. (Original.)

● Single infestation found in winter 1909–10.
X Infestations found in winter of 1910–11.

The town of Holden, which is directly west of West Boylston, shows an increase quite similar to those already mentioned. A single female pupa was found during the winter of 1907–8, but the following year nothing was discovered when the scout was made. In the winter of 1909–10 nine estates were found infested, each with a single egg cluster, while in 1910–11 10 estates were infested with 45 egg clusters. In 1911–12 a large increase was found, 455 being discovered on 67 estates.

The city of Worcester is located south of Holden, and was first found infested in the summer of 1907, when Mr. D. M. Rogers found a few caterpillars on an estate on Hope Avenue. During the winter of 1907–8 the city was scouted and 44 egg clusters were found on seven estates. These were well scattered over the city, and, owing

to the large traffic by automobiles and trolley cars from the badly infested district in eastern Massachusetts, it is very probable that the infestation may have been brought about by the carriage of caterpillars in this way. These colonies received careful attention during the summer. In the winter of 1908–9 16 estates were found infested with a total of 32 egg clusters. Fourteen of these estates were near Worcester Academy; the other two were in the eastern section of the city. Only a few egg clusters were found on the estates which were infested the previous year. In 1909–10 10 infested estates were found, with a total of 31 egg clusters, well scattered through the city. Only one of these was on property which was found infested the previous year. In 1910–11 275 egg clusters were found on 145 estates, every section of the city being included in the infested area. In 1911–12 3,570 egg clusters were found on 424 estates. It seems probable that during the period from 1907 to 1910 the greater part of the infestation may have come from traffic, but one can not escape the conviction that during the summers of 1910 and 1911, as the infestation to the south and southeast became more pronounced, a large number of the colonies resulted from wind spread. It should be remembered that the chances for spread by traffic in a large city are far greater than in the country districts. The data concerning Worcester are given because the city resembles many of the towns mentioned, inasmuch as it is very hilly, so that spread by air currents is very probable.

The town of Millbury, which adjoins Worcester on the south, has a record which is of considerable interest, inasmuch as the infestation has been decreasing from year to year. In the winter of 1907–8 32 egg clusters were found on five estates. These were all located in the central part of the town not far from the railroad. The following year no new egg clusters were found in these localities, but two other infestations, containing 12 egg clusters, were located, one near an infestation of the previous year, close by the railroad, and the other a considerable distance west of any previous infestation. In the winter of 1909–10 three new infestations were found, each containing an egg cluster, but no clusters were found in the old infested area. In the winter of 1910–11 nothing was found in the area infested the previous year, but three separate infestations, containing four egg clusters, were found in the Bond Hill section of the town east of the railroad. In 1911–12 33 egg clusters were found in six localities. The conditions in this town are quite different from those in any town previously mentioned. So far as is known, no bad infestations occurred in the region directly south, so that there would be far less opportunity for spread by the wind than would be the case in the other towns mentioned. It seems probable

that early infestations may have been brought about by automobile traffic, but this, of course, can not be proved.

The data from the two towns of Pepperell and Townsend, which are nearly due north from the towns already mentioned and are bounded on the north by the New Hampshire State line, have been furnished by the local moth superintendents, Mr. J. Tune and Mr. George E. King, and are given, as they show a contrast in the increase in infestation over most of the towns already mentioned.

The town of Pepperell was found infested the same year as were the town of Westboro and the city of Worcester. It lies about 40 miles north of Westboro, and instead of immediately adjoining towns that were infested with the gipsy moth in 1905, as was the case in the town of Westboro, it is located more than 12 miles from the nearest town that was found infested at that time. In the winter of 1906–7 4 egg clusters were found near the center of the town by State inspectors. These were properly treated, and during the following winter 87 egg clusters were discovered and creosoted. In the winter of 1908–9 756 egg clusters were found, and since that time the insect has become so abundant that no effort has been made by the local moth superintendent to keep a record of those that were found and treated.

The town of Townsend adjoins Pepperell on the west, and was first found infested one year later than the towns of Pepperell and Westboro, and the same year as the towns of Holden and Millbury, a record of which has already been given. The infestation in Townsend is interesting, inasmuch as the record has been carefully kept by the local superintendent, Mr. George E. King. In the winter of 1907–8 1 egg cluster was found in the western part of the town. It was treated with creosote, the trees were burlaped, and later 5 caterpillars were found and destroyed. In the winter of 1908–9 1 egg cluster was found in the eastern part of the town and treated in the same way, and 3 egg clusters were found near the center of the town, and as a result of burlaping 15 caterpillars were killed during the summer. The following winter 65 different colonies were found scattered throughout the town. Five hundred and twenty-four egg clusters were treated and 10,500 caterpillars were destroyed during the summer. During the winter of 1910–11, 245 colonies were found scattered throughout the town, a large number being in orchards along roadways. In these colonies 3,613 egg clusters were destroyed, and later in the season about 20,000 caterpillars were killed. On February 27, 1912, Mr. King informed me that 12,862 egg clusters had been found in 257 localities, and that the work for the winter of 1911–12 was not nearly completed. The increase in the number of colonies found and the number of egg clusters and caterpillars destroyed is in marked contrast to the

record of infestation of Westboro, which was much nearer the badly infested territory, and, other things being equal, should have become badly infested sooner than Townsend, where the first infestation was located a year later.

The scouting of Dunbarton and Farmington, N. H., has been carried on by scouts working under the direction of Mr. D. M. Rogers, and Table VII shows that the infestation has been greater than that in the towns given in central Massachusetts, and about the same as that found in Townsend.

It will be observed that in Westboro seven colonies, containing 377 egg clusters, were found in 1906–7, which indicates that the moth was present the previous year, and probably would have been found if there had been sufficient time to make a thorough inspection. In the winter of 1911–12 214 colonies were found and 1,897 egg clusters were treated. When this is compared with the record given for Townsend, which started from one egg cluster in the winter of 1907–8, one can not escape the conviction, inasmuch as most of the infestations recorded in the winter of 1911–12 were in localities which had previously not been known to be infested, that the rapid infestation of this territory was due to the dispersion of young caterpillars by the wind.

PLANS FOR SCOUTING WOODLAND AREAS.

Many data have been given showing that the dispersion of the gipsy moth is largely due to small caterpillars carried by the wind, but it seemed desirable to determine whether the woodland areas in the towns where only a few colonies existed were becoming infested by this insect. The matter was thoroughly discussed by Messrs. Fiske, Rogers, and the writer, and as a result plans were made to scout large areas in several of the outlying towns. The plans were approved by Dr. L. O. Howard. It was arranged that the scouting work should be carried on under the direction of Mr. Rogers, and it was begun in October, 1911. Owing to the severe winter and heavy snowfall in the infested territory it was impossible to finish all the towns until late in the spring of 1912. The work was carried through, however, and a statement of the results follows.

The original plan contemplated the examination of every tree in the whole or a part of the towns of Lisbon and Yarmouth, Me., Milton, Tilton, and Bennington, N. H., and Gardner, Grafton, and Wareham, Mass. (See fig. 6.) It will be noted that these towns are located in the sparsely infested area (map 1), and it was expected that some interesting data on wind dispersion would be secured. Work in Bennington, N. H., was carried on under the direction of General Foreman I. L. Bailey; that in Maine and in Tilton and Milton, N. H., and Grafton, Mass., was directed by General Foreman H. L. McIn-

tyre. The work in Wareham was carried on under the direction of C. E. Totman and C. B. Whitaker, while that in Gardner was directed by Henry N. Bean. It should be noted at the outset that the character of the forest has a great influence on the liability to infestation, because if the caterpillars are carried by the wind and dropped upon trees upon which they can not feed, no infestation will result. Therefore it is to be expected that in sections where coniferous trees predominate the chances of new infestation will diminish, even although the region is in line with the prevailing wind during the time the caterpillars are likely to be carried by it.

RECORD OF SCOUTING IN LISBON, ME.

On October 23, 1911, the work in Lisbon, Me., was begun by Mr. C. E. Totman and a crew of experienced scouts, and the territory north of the Androscoggin River and east of the Maine Central Railroad was examined. This covered about 16½ square miles, about 40 per cent of which was woodland. The land in this town is rolling, and a considerable portion is cleared and cultivated.

The percentages of the various kinds of trees in the regions scouted were estimated by Mr. Totman, as follows:

	Per cent.		Per cent.
Conifers	40	Elm	2
Oak	3	Birch	7
Maple	17	Beech	18
Ash	7	Miscellaneous	6

It will be noted that about half of the food plants (conifers and ash) are unsuitable for food for first-stage gipsy-moth caterpillars, so that of the 16½ square miles covered only 3¼ square miles of the area supported trees upon which the gipsy moth would survive if it were introduced. The oak, which is the favorite food, comprised only 3 per cent of the tree growth. Roadsides in this town were scouted in the winter of 1910–11, and nine infestations were found in the territory under consideration, a single egg cluster being obtained in each locality. These were treated at the time. The results of the present scouting showed that no infestations were present where eggs were found last year, but 18 new infestations were located. Only one of these was in woodland, and in this case seven egg clusters were found on the bank of the Sabattus River. Thirteen egg clusters were found on trees along the roadside, east of the town, and two were located on another road near by. Each of the remaining infestations at different points along the highway contained a single egg cluster or a pupal case. It is improbable that the infestations along these roads resulted from previous infestations, although a few egg clusters may have been overlooked. Lisbon is located at least 70 miles from badly infested territory, so that bad woodland infestations were hardly to be expected.

FIG. 6.—Map showing towns and cities in New England where woodland scouting was done, 1911–12. (Original.)

RECORD OF SCOUTING IN YARMOUTH, ME.

Scouting operations were commenced in Yarmouth, Me., on October 23, 1911, by a crew of experienced scouts under the control of Mr. A. M. G. Soule. All the territory east of the Grand Trunk Railroad and south of the Maine Central Railroad, about 7 square miles, was examined. This section of the town of Yarmouth consists largely of cleared land and pastures. The wooded areas are in relatively small blocks, less than 3 square miles of the area being in woodland. The tree growth was rated by Mr. Soule as follows:

	Per cent.		Per cent.
Conifers	30	Birch	11
Oak	49	Miscellaneous	9
Maple	1		

It will be noted that nearly one-half of the trees in the area are oak; that conifers were 10 per cent less than in the district scouted in Lisbon; and that the area, although smaller, was more suited to rapid infestation, owing to the character of the tree growth.

During the winter of 1910–11 15 infestations were found in the entire town, 7 of them being in the area under consideration. All of these places were along the highways or in orchards. Five of the seven each had a single egg cluster, one had two clusters, and in the other a pupal case was secured. No egg clusters were found in these places this year, but a total of 27 infestations, containing 56 egg clusters, was discovered. Five of the colonies were in woodland, and in one of them 17 new clusters and 1 old one were found.

Yarmouth is located nearer the badly infested area than Lisbon, and more woodland infestations should be expected than in the case of the latter town.

RECORD OF SCOUTING IN MILTON, N. H.

On October 25, 1911, a crew of experienced scouts under the direction of William Sarsfield commenced the examination of the trees in Milton east of the Boston & Maine Railroad. This territory is hilly and the towns south and southwest of it are generally very badly infested. The area examined covered about 18 square miles, 13 of which are wooded. The forest growth was as follows, according to estimates furnished by Mr. Sarsfield:

	Per cent.		Per cent.
Conifers	29	Elm	4
Oak	13	Beech	29
Maple	16	Miscellaneous	7
Ash	2		

In the winter of 1910–11 the orchards in this area were scouted and 21 infestations were found, practically all of which had a single egg cluster. In the whole town, the greater area of which is on the west side of the railroad, 159 egg clusters were found in 55 localities.

In 1911–12 14 woodland infestations of 59 egg clusters and 22 orchard and roadside infestations of 202 clusters were found east of the railroad. The woodland infestations were in the territory between the Milton railroad station and the south end of the town. In the part of the town west of the railroad only the roadsides and orchards were examined, and 6,602 egg clusters were found in 57 localities.

The results of scouting in this town show that the infestation is increasing rapidly in both woodland and orchards. The figures for the two years are significant, for in the western part of the town the infested localities in one year more than doubled, and the number of egg clusters was more than 40 times greater than the previous year.

RECORD OF SCOUTING IN TILTON, N. H.

Examination of Tilton, N. H., was begun November 1, 1911, by Mr. C. E. Boardman and a crew of experienced scouts. The area of the town is about 10 square miles, less than one-third of this being wooded. According to Mr. Boardman's estimates the tree growth is as follows:

	Per cent.		Per cent.
Conifers	30	Elm	2
Oak	13	Birch	12
Maple	35	Miscellaneous	6
Ash	2		

In 1910–11 the roadsides and orchards in the town were scouted, and four infestations containing 889 clusters were found. In one of these over 800 clusters were treated, and during the following summer over 4,800 caterpillars and pupæ were destroyed under burlap. As a result of the present scout only 11 egg clusters were found in three orchard and two woodland infestations, one of the latter being near the bad infestation of the previous year. This shows that good work was done in controlling and reducing the infestations found and that reinfestation by natural or artificial spread in this area has been slow.

Tilton is located 20 miles north of Concord, N. H., and most of the badly infested area lies to the southeast; some, however, is near Concord and extends to the south.

RECORD OF SCOUTING IN BENNINGTON, N. H.

Bennington is located about 25 miles west of Manchester, N. H. The land in the eastern part of the town forms a part of the watershed of the Merrimac and Contocook Rivers. Almost one-half of the area is wooded. An examination of this town was begun

November 1, 1911, by scouts in charge of Mr. W. T. Kelly. The tree growth was rated by him as follows:

	Per cent.		Per cent.
Conifers	25	Ash	2
Oak	21	Birch	27
Maple	25	Miscellaneous	10

In all about 5 square miles of woodland were scouted, and as the town is very hilly it was hoped that evidence of wind dispersion might be found on the high land.

In the winter of 1910–11 the roadsides and orchards were examined, and eight egg clusters were found in two localities. As a result of the present scouting no infestations were discovered in these places, but two new orchard colonies, one containing eight and the other three egg clusters, were found. No egg clusters were found in the woodland.

Practically all of the badly infested territory lies to the east and south.

RECORD OF SCOUTING IN GARDNER, MASS.

On April 26, 1912, scouting in Gardner, Mass., was begun by Mr. F. W. Foster and a crew of experienced scouts working under the direction of Mr. H. N. Bean. A part of the woodland west of the Boston & Maine Railroad and north of the Fitchburg Railroad, covering almost 2,368 acres, was examined. Owing to the predominence of coniferous and sprout growth two other areas were selected north and east of the town, where deciduous trees were abundant.

Gardner is on the ridge of land which forms the watershed of the Connecticut and Merrimac Rivers and their tributaries, and on account of its elevation, about 1,300 feet above sea level, it was thought that evidence of wind spread of the larvæ might be found. The examination showed, however, that the forest growth was not favorable for infestation. The season is considerably later in this locality than in the lower land near Boston.

Gardner is a large chair-manufacturing center, and most of the hardwood has been cut off, presumably to be used for that purpose.

The kinds of tree growth examined were rated by Mr. Foster as follows:

	Per cent.		Per cent.
Conifers	67	Beech	3
Oak	2	Birch	10
Maple	13	Miscellaneous	5

Many orchards in this city are slightly infested, but no large colonies have ever been found. The scouting work resulted in the discovery of only one infestation in woodland which was located far enough from orchard infestations so that the larvæ might have been

carried a considerable distance by the wind. The infestation mentioned was in a small block of woodland, mostly deciduous growth, which borders Crystal Lake, and is west of Woodland Avenue, and in this place four new egg clusters were found. Another infestation of a single egg cluster was on a maple tree 500 feet from the highway, but there were two infested orchards within 1,000 feet, and it is probable that the spread came from these orchards. The caterpillars may have been carried by the wind or on men or animals. A third infestation was found near the Winchendon line, but egg clusters had been previously discovered on several old apple trees in a pasture near the woodland.

Any of these colonies may have been brought about by wind spread, but the evidence is not strong. The unfavorable character of the trees would prevent, to a large degree, the establishment of the insect in woodland in this town.

RECORD OF SCOUTING IN GRAFTON, MASS.

On March 11, 1912 an examination of Grafton, Mass., was begun by scouts working under the direction of Mr. H. L. McIntyre. All the territory east of the Grafton & Upton Railway was examined, and a part of the woodland near Farnumsville was also scouted. The town is generally infested with the gipsy moth, and it is possible to find egg clusters in nearly every orchard. The area examined covered about 5 square miles of woodland. No orchards or estates were scouted. The different kinds of trees in the woodland were estimated as follows:

	Per cent.		Per cent.
Conifers	6	Chestnut	18
Oak	21	Ash	1
Maple	23	Birch and beech	14
Elm	1	Miscellaneous	16

As a result of the scouting the following infestations were located:

One old egg cluster on a birch tree in woodland near North Grafton, two colonies on the land of the State insane hospital, one of 18 egg clusters near the barns, and the other of 25 egg clusters on a large oak tree on the edge of the woodland in the rear of one of the buildings. As there is quite a general infestation of the fruit trees on these grounds it is probable that these colonies were established by caterpillars carried on men or farm animals to the places where the egg clusters were found. An infestation of two clusters was located near the Westboro line in oak growth. Five infestations were found in two blocks of woodland on Esterbrook Avenue. In one block, where three colonies were found, four egg masses were discovered, three new and one old, while in the other

block two colonies on low land totalled 149 new and 27 old egg masses. Most of the trees in these areas were pine, maple, and birch, with a few oaks and chestnuts. On the whole, these colonies were not very favorably situated for rapid increase of the species. One old egg cluster was found in woodland south of Grafton Center, and a colony of 20 nests was found on two apple trees in a block of woodland near Farnumsville.

The discovery of old egg clusters is noted above, because it is probable that new clusters were present in obscure places on the tree or on the ground and were not observed by the scouts. During a part of the time several inches of snow covered the ground.

In all the places mentioned it is probable that five infestations may have been brought about by wind spread, although this can not be stated with certainty owing to the state of infestation of the orchards in the town. Grafton was first found infested in the winter of 1908–9. It is located only 7 miles west of Hopkinton, where the gipsy moth was found in 1905.

RECORD OF SCOUTING IN WAREHAM, MASS.

Scouting in Wareham was begun March 28, 1912. As it was impossible to secure definite results by examining a section of the town on account of the prevalence of coniferous growth, several areas were selected, covering in all about 925 acres, and a scout of this territory was made.

This area was used because hardwood growth predominated and, on the average, about 75 per cent of it was oak.

As a result of the examination 112 egg clusters were discovered in eight localities.

Two small infestations were found near the road leading from the Tremont station; another was in woodland near West Wareham, 50 egg clusters having been found. The white pine in this area had been cut, so that only deciduous trees remained. A short distance away were located trees that had been infested for two or three years, and this may explain the source of this colony.

A block of dead oak growth on high land near West Wareham contained two colonies, one of 50 and the other of 2 egg clusters. Apparently these were caused by wind spread, as there were no infested places near by, so far as could be ascertained.

Three other colonies, of a single egg cluster each, were located. One was on the back road between Wareham and West Wareham, and the other two were southeast of the Wareham railroad station. Two of these may have been brought about by wind spread, but the third was near the site of a colony which had been treated for several years.

The result in Wareham indicates that there may have been some dispersion by the wind, but only a few of the colonies can be accounted for in that way.

RESULTS OF SCOUTING WOODLAND AREA.

On the whole, the number of woodland infestations found is not so large as might be expected. Those at Milton, N. H., and Yarmouth, Me., are the most striking, probably furnishing the most definite results of any of the towns under consideration. Owing to the long distance from Lisbon, Me., to the nearest badly infested area, which is about 70 miles, and to the large quantity of unfavorable food for the caterpillars, it is not surprising that little evidence was secured to show that the infestations were caused by the wind. The other infestations in the town, however, indicate that there may have been a short-distance spread in this way. In Yarmouth, Me., the proportion of coniferous growth was practically the same as that in Milton, N. H., but the wooded area examined was only about one-fourth of that scouted in the latter town. Oak trees, however, predominate in the woodland in Yarmouth; hence it is not surprising that a larger number of colonies were found in that town than in Lisbon. More woodland colonies were found in Milton than in any other town, and this is what would naturally be expected, as it is near badly infested towns and is located so that the prevailing wind would convey large numbers of the small caterpillars. The woodland examined contained only about 13 per cent of oak. If this species had been as abundant in Milton as it was in Yarmouth far more serious infestations would probably have resulted.

Scouting in Tilton indicates that good work was done in suppressing the gipsy moth during 1910 and 1911. The town is located a little out of the line of wind dispersion, and this, coupled with careful hand work, has evidently resulted in the satisfactory condition which has been reported.

The results in Bennington, N. H., a town which is located on high land, where 21 per cent of the trees are oak, point strongly to the fact that the woodlands do not become infested rapidly when they are located in a region unfavorable for larval spread by the wind. Although about 5 square miles were examined in this town, no woodland infestation was found; and when it is remembered that this area is less than 10 miles from towns which were found infested in 1908 and 1909, the evidence is further strengthened. The danger of artificial spread of gipsy-moth caterpillars on vehicles is probably less in this town than in any of the towns where woodland areas have been scouted.

The scouting in Gardner and Wareham, Mass., was handicapped by the fact that the woodland growth was not satisfactory for the

establishment of the species, although the selection of areas containing the most deciduous growth in both towns aided in securing more satisfactory data.

Wareham was found infested in 1905, and if the town had been located along the line of prevailing winds at the time the gipsy-moth caterpillars were in the first stage, the woodlands would probably be as badly infested as those in towns an equal distance north or northeast of the original infested area. This is not the case, however, which indicates in itself that unfavorable food and practical immunity from winds favorable for spread have worked to the advantage of this town.

The same statement can be made of both Gardner and Grafton, which were found infested in the winter of 1907–8. It is true that there are a considerable number of small roadside and orchard infestations in these towns, particularly in Grafton, but travel is heavy during the early summer and an excellent opportunity is offered for the spread of the larvæ on vehicles and automobiles. If wind spread were not a prime factor in distributing the gipsy moth, the woodland in Grafton should be more heavily infested than the wooded area examined in Milton, N. H., because the latter town is much farther from the original center of infestation, and was first found infested a year later.

It is practically impossible to explain the origin of many separate infestations; but taking the woodland areas examined and studying them in relation to each other and in relation to the badly infested area, it is evident that the theory already given concerning wind spread is confirmed.

It is surprising, when all the facts are considered, that so much good work has been done in controlling the gipsy moth in many of the infested towns. Large numbers of cases are on record where all the infestations in a town have practically been cleared of this insect in a single year; but, owing to general wind spread, as many and usually more colonies have been found in other parts of the same town the next year. This is one of the discouraging features of the work and renders it extremely difficult to control the insect in towns which are most subject to natural spread by the wind. It is obvious that if this is to be brought about, bad colonies must be subdued, particularly those which are nearest the outside border of infestation, because, as has already been pointed out, the farther the larvæ are carried by the wind the less the chance becomes for them to establish the species, owing to their wide separation from other specimens and the limited opportunity of their finding suitable food for full development.

EFFECT OF WIND SPREAD ON THE PROBLEM OF GIPSY-MOTH CONTROL.

The fact that gipsy-moth caterpillars are spread chiefly by wind during the time they are in the first stage and that for this reason the present spread of the insect is toward the northeast, northwest, and north has been sufficiently demonstrated. Another factor which enters into the problem to a greater or less extent, and which has an important bearing on the spread of young caterpillars by air currents, is the altitude of the woodland in the various towns.

Whether high altitudes are more likely to become infested in this way than low areas it is difficult to state, but there can be no question in regard to the difference in temperature of winds after having passed over an area of high land. For example, the cold winds which sweep down the New England coast from the northeast and east are not accompanied by as low temperature, nor are such winds as cold or penetrating in the central part of Massachusetts as they are along the seacoast. As high winds must be accompanied by high temperature in order to bring about the spread of young caterpillars, it can be stated that after the territory on the west side of the watershed in Massachusetts and New Hampshire becomes infested to such a degree that large areas are defoliated, the spread of the young caterpillars by wind will be more far-reaching and more rapid than it has been at any period since the moth first became established. It is indeed a fortunate thing that the gipsy moth first found lodgment on the North Atlantic seaboard, on account of the various elements which have worked together to restrict its spread. If the insect had first escaped in central Massachusetts, in Connecticut, or in New York State there would have been ample opportunity for spread in all directions, and it would have been difficult to restrict it to anything like the area which it now occupies.

SUMMARY.

The gipsy moth is spread by local and long-distance means.

Local spread may be due to the transportation of caterpillars or egg clusters on carriages or wagons that move for only a short distance outside the infested territory. The egg clusters may be carried on driftwood which floats down rivers during the spring.

Long-distance spread may be due to the shipment of egg clusters on lumber products, nursery stock, or boxes from the infested territory to any points where such goods are unloaded. Caterpillars may be, and often are, carried long distances on automobiles or trolley cars, and cases are on record where colonies have been established in this way.

By far the greatest dispersion is due to the fact that first-stage caterpillars are blown by the wind. A glance at the present infested territory shows that dispersion has been along the line of the prevailing winds immediately following the hatching of the caterpillars. One condition favoring wind spread is the presence of large woodland colonies which are overpopulated with caterpillars. This stimulates activity on the part of the insects in search of food and affords opportunities for them to be carried away by the wind. High temperature increases the activity of the caterpillars, and this tends to increase the chances of their being blown away. Weather records for the past 10 years show that the prevailing winds during April and May, when the temperature is high enough to make the caterpillars sufficiently active, and when the wind is strong enough to blow them for any great distance, are for the most part from the south and southwest.

The character of the food has a very important bearing on the dispersion of this insect, because unless caterpillars that are blown by the wind are able to find lodgment on favorable plants they will not survive, and there will be no opportunity for the species to become established. If a number of first-stage caterpillars were dropped by the wind into a forest of solid pine they would not be able to establish a colony, because these small caterpillars can not survive on pine foliage. There are other trees, particularly conifers, which are equally immune from injury by the first-stage caterpillars, and upon which they are not able to develop. This shows that large blocks of unfavorable food plants will not only prevent the establishment of the insect, but that such woodland will require no treatment whatever, provided it is isolated by removing the favored food plants near by.

RECOMMENDATIONS.

As a result of the experiments which have been conducted and a study of the data which have been secured, the following recommendations are made, as these have a practical bearing on the gipsy-moth problem:

(1) National legislation should be enacted to provide for the inspection of lumber products or other material which is likely to carry the gipsy moth from the territory which is now infested to uninfested regions. This is particularly important and is distinctly of national concern, because goods of this sort are often shipped to far distant points in the United States, and without careful scrutiny excellent opportunities are offered for establishing new colonies remote from the area in New England which is now infested.

(2) Inasmuch as certain coniferous trees, if grown in solid stands, will not furnish favorable food for small gipsy-moth caterpillars that might be distributed by wind spread, and as some of our decidu-

ous trees will probably furnish similar unfavorable food conditions, it seems very important to determine by careful experiment the susceptibility to gipsy-moth attack of the various species of native trees in New England forests and to test different methods of thinning woodlands in order to reduce the infestation by furnishing unfavorable food, and by so doing to prevent the area thus treated from becoming so badly infested as to enable caterpillars to be spread from it by the wind. These experiments are now under way.

(3) The experiments conducted indicate that little spread by the wind will result unless badly infested areas exist. Inasmuch as the principal spread over a wide area is due to the wind, more attention should be paid to the proper handling of bad woodland colonies along the lines already indicated, in order to prevent widespread distribution. From the experiments conducted, and from the data examined, and as a result of interviews and conversation with various officials and parties interested in moth work, it appears that the spread of the gipsy moth at the present time by automobiles or other traffic is far less serious than heretofore. Already a large mileage of trees along trunk roads has been thinned and protected, so that the danger has been largely reduced in this way. Special attention has been given to many roads leading to and from summer resorts or camping places where automobile traffic is heavy during the summer, and as a result of this work and of the scouting which has been carried on in the outlying territory, which included an examination of the trees along many of the trunk roads in uninfested sections of the State as well as an inspection of places, such as hotel grounds, where touring parties would be likely to stop, it has become quite evident that in the last year or so the danger of infestation by means of automobiles has been greatly reduced. This would indicate the desirability of reducing the thinning operations along roadways, except on those where the automobile traffic is the heaviest during May and June.

(4) The work which has to do with the determination of the limits of spread of the insect, and which is known as the scouting, is of great importance. This is being carried on in the outside infested towns and in those adjoining, and too much stress can not be laid on its thorough prosecution. The men actively engaged in it should be instructed thoroughly in regard to the best methods of thinning woodland in order to control the moth, so that practical advice can be given to the owners of forest land to stimulate them to take proper measures for protecting their property before the infestation becomes serious enough to cause severe injury.

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